FINAL

ENVIRONMENTAL ASSESSMENT FOR

DUNE WORK

AT PRIME HOOK NATIONAL WILDLIFE REFUGE

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I. SUMMARY OF PROPOSED ACTION

The U.S. Fish and Wildlife Service (Service) proposes short-term, interim measures to scrape sand from washover areas in Unit II on Prime Hook National Wildlife Refuge (NWR) to build up approximately 3,000 feet of dunes south of Fowler Beach, and fill recently created inlets. This work will largely, but not entirely, reconfigure sand located on refuge lands into a higher dune or berm. The final action, which the Service proposes to implement, incorporates components of Alternative 2 (the original Preferred Alternative) and Alternative 3. It will also allow the State of Delaware access across refuge lands with trucks and equipment to import sand from outside sources and place it on private lands, as the State determines is appropriate and fundable. The primary purpose of this action is to maintain current habitats in as stable a condition as possible to prevent disintegration of the marsh substrate and peat while technical information is generated and long-term restoration actions are developed.

In the area of the recently created inlets, the Service currently owns approximately 700 feet of the barrier island separating the marshes of Unit II from Delaware Bay. Private landowners own about 3,200 feet. The Service owns all of the marshes behind the barrier island. The revised Proposed Action will reconfigure sediment scraped from refuge lands to construct a dune/berm as far west (landward) as feasible. However, some overwash sand from refuge land will also be used to fill in other mini-inlet(s) on private property within the approved refuge acquisition boundary south of Fowler Beach Road. Staging of equipment, sand, and personnel may take place on refuge land during project construction.

The Service also evaluated the following alternatives:

- Alternative 1 (No Action)
- Alternative 3: Dune line reconstruction using material from off-site sources

The key differences between the action proposed at present and those proposed in the Draft Environmental Assessment (EA) issued on July 27, 2010, is that both Alternatives 2 and 3 may be utilized and the alignment of the dune/berm will be as far landward (west) as possible, remaining primarily on the refuge. This short-term, interim action will be pursued only until long-term decisions for management of the refuge are made via the final comprehensive conservation plan (CCP), the draft of which is anticipated to be released in winter 2010.

In addition to these three alternatives, we have also considered several other alternatives, which are not being pursued given the short-term nature of the current action, but are appropriate for subsequent consideration by the Service or the State of Delaware on a long-term basis.

II. INTRODUCTION

A. Document Purpose and Structure

The Service has prepared this EA in compliance with the National Environmental Policy Act (NEPA) to ensure that we are acting in accordance with the letter and spirit of NEPA to foster excellent action, make decisions based on the environmental consequences, and take actions to protect, restore, and enhance the environment (40 CFR 1500-1508).

The purpose of this EA is to determine if the Proposed Action will have significant impacts to the environment, to address unresolved environmental issues, to discuss legal and policy concerns raised by this proposal, to document the basis for a decision on the proposal, and to facilitate interagency coordination between the Service and the Shoreline and Waterway Management Section (SWMS) of the Delaware Department of Natural Resources and Environmental Control (DNREC) concerning our joint missions to manage and protect natural and cultural resources. This EA discloses the direct, indirect, and cumulative environmental impacts that would result from the Proposed Action and alternatives.

B. Background and History

Prime Hook NWR was established in 1963. According to historic surveys and maps, the area consisted of extensive salt marsh and brackish marsh interspersed with fresh marsh areas (Chamberlain 1951, DNREC 1971 maps on file). The area was heavily altered by human activity through mosquito and drainage ditching, drainage of low-lying uplands, and other alterations. Much of the former salt marsh community had been invaded by *Phragmites australis* (*Phragmites*), an invasive exotic wetland plant which establishes readily in altered or disturbed wetlands. Prior to 1988, a barrier dune system separated an inland salt marsh from the waters of Delaware Bay. Development existed in the Slaughter Beach area to the north and the Primehook Beach community to the south. Salt water entered the marsh system through Slaughter Canal via Cedar Creek and the Mispillion River.

In 1988, the Service and the State of Delaware created two freshwater impoundments totaling approximately 4,000 acres, now referred to as Units II and III (USFWS 1982, USFWS 1986) (Figure 1). The 1986 EA describes the area as containing both a “former high quality freshwater marsh” and salt marsh vegetation. In addition, that EA describes grid-ditching that was conducted in the units during the 1930s and 1940s, and indicates that high quality marsh still existed in the 1950s. Grid-ditching is a technique used in salt marshes during that era to alter drainage patterns for mosquito control. It did not generally occur in freshwater marshes. It is clear from all accounts that the area historically contained a mix of vegetation, including well-established salt marsh communities, although the exact composition and distribution of species may have fluctuated over the years in response to both natural and human-induced changing conditions. Salt marsh habitat that occurred prior to construction of the impoundments may have been degraded, intermingled with pockets of freshwater vegetation as freshwater collected in excavated and natural pools, and subjected to ditching, draining, and other alterations. Due to the obstruction and attenuation of tidal flows by roads, ditches, and canals, both Units II and III changed from salt marsh-dominated habitats to fresh/slightly brackish water pond habitats. Large portions were invaded by *Phragmites*, prompting concerns regarding reduced quality of wildlife habitat as well as fire safety.

Units I and IV have remained tidally influenced salt marsh habitats and are not proposed to be altered pursuant to this EA.

Figure 1. Prime Hook NWR Vicinity Map.

The purpose of the impoundment project was to convert existing, degraded salt marsh and brackish wetlands to a freshwater system with water level management capability to improve habitat conditions for wintering waterfowl. The natural, undeveloped dune line/overwash system from the last house on Slaughter Beach at Unit I south to the first house at Primehook Beach community in Unit II covered approximately three miles of shoreline. The natural dune system was a discontinuous, low mound and/or ridge system interspersed with overwash areas that regularly migrated along the barrier. Some areas were covered with vegetation while others were bare. Unit II (south of Fowler Beach Road) was largely created directly behind this natural dune system, while the more southern Unit III was separated from Delaware Bay due to its location behind the developed Primehook and Broadkill Beach communities.

The Service's application for a State permit to impound the degraded marsh included the construction of a large concrete water control structure with nine bays to hold stop logs, but did not include work to mechanically change the dune system. Establishment of the impoundments utilized existing State roads as dike infrastructure (Fowler Beach, Prime Hook and Broadkill Roads), without involving any changes to those existing roads (such as increasing road elevation). The Delaware Bay shoreline parallel to Unit II at that time was located about 150 feet eastward of its current position. Portions of the shoreline along the refuge, particularly in Unit II, have migrated about 150 to 200 feet in the last 24 years.

The Service produced an EA in 1986 covering the actions of converting the degraded salt marsh areas to freshwater impoundments. This EA did not explicitly discuss how the bayside dune or berms would be maintained if storm action or erosion lowered them. It did, however, acknowledge that one source of water for the impoundment to be created could be overwash of the dunes (USFWS 1986).

The final State permit included a condition for the Service to construct a higher and contiguous dune line across the three-mile-long stretch of shoreline described above (along Units I and II). The Service did not plan nor budget any shoreline work. Instead, the Delaware Department of Natural Resources and Environmental Control conducted all dune line manipulation prior to project completion by pushing sand east from the overwash area to create a low dune. At that time, most of the barrier island was in private ownership. In 1999, DNREC, under cooperative agreement, again moved sand east from the overwash fans towards Delaware Bay to re-create the dune for Units I and II.

This dune line was overwashed and breached in small segments along Unit I (north of Fowler Beach Road) beginning in 1991. Continual breaching of Unit I dune lines created expansive overwash areas, and a new mini-inlet was formed by Hurricane Ernesto storm surge and wave fetch in 2006. Because this unit had always been managed as a salt marsh, even after impoundment construction, the Service decided in 2008 to no longer repair the Unit I dune line and the system is allowed to function naturally today.

The dune line in Unit II (south of Fowler Beach Road) remained unbreached until two strong, back-to-back Nor'easters demolished dunes in 1998, creating wide overwash bands into the impoundment. The Lewes tide gauge, which is located about 9 miles

southeast of the refuge, generally records a mean sea level range of 4.08 feet and a diurnal range of 4.65 feet. Water levels attributed to the storm surges included 11.40 feet on January 28, 1998, and 11.27 feet on February 25, 1998 (http://tidesandcurrents.noaa.gov). No inlets were formed as a result of the storm, and in 1999, dune line repair work, again conducted by the State, was considered minor. It again involved pushing the sand from the overwash fan eastward to heighten the dunes.

Repairs to the Unit II dune line damaged by Hurricane Ernesto in 2006 were also minor and the State pushed sand from the overwash fan eastward to re-form a dune (under contract from the Service). In 2008, sand was again scraped and bulldozed to replace the stationary dune line that was lost due to storm activity. The Service paid for that work and Service personnel performed the work on privately owned portions of the dune line, which was considered routine and reasonable maintenance to sustain the freshwater system within Unit II. More recently, however, the increasing frequency of dune overwash events and the significant alteration of the dunes that they cause have elevated such dune modification activities beyond the level of infrequent and minor repairs.

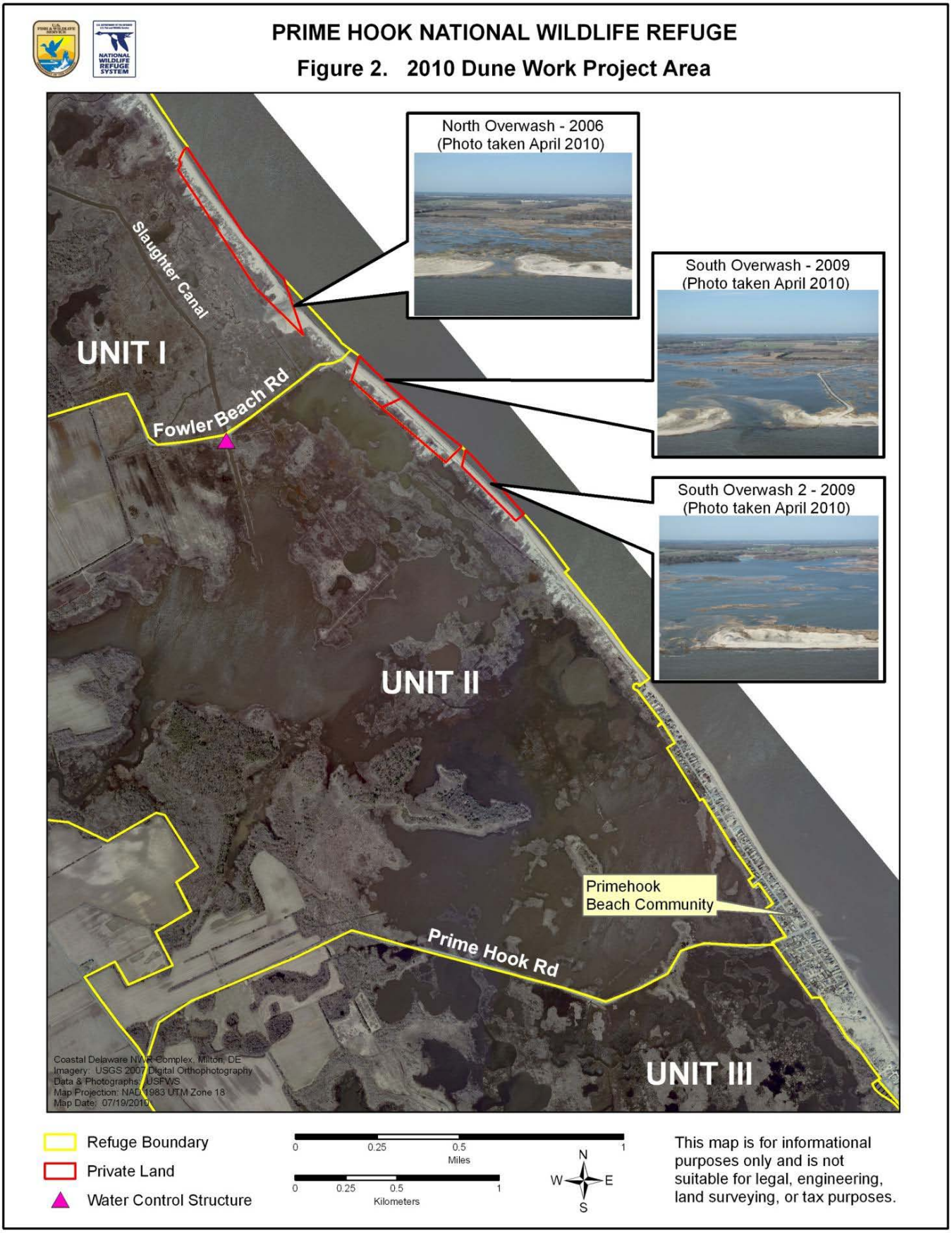
Repeated Nor'easter storm events in fall/winter 2009 created storm surge conditions that overwashed the dune line along Unit II, and breached underlying remnant marshes along an area immediately south of Fowler Beach Road. Water level data were recorded on October 17-18, 2009 (10.12 and 10.01 feet, respectively), and again on November 12-13, 2009 (10.53 and 10.37 feet, respectively). Higher than normal water levels were also recorded on December 19, 2009 (9.91 feet), and on March 13, 2010 (9.67 feet). All of these storm events created extreme coastal flooding of refuge lands, public roads, and adjacent private beach properties, as well as erosion and repositioning of refuge shoreline and sandy beach habitats. Additionally, a mini-inlet formed, which severely eroded the dune line. It is currently accommodating a substantial overwash, which is facilitating the flow of tidal waters from Delaware Bay into Unit II (Figure 2).

C. Current Conditions

Although the exact acreage of the overwash has not been measured, it appears that approximately 20 acres of former marsh/open water on the eastern edge of the Unit II impoundment are now covered with sand. The tide flows in and out of the site, twice daily. None of the overwashed area has revegetated as yet. Prior to inlet formation, Unit II only received saltwater from the bay during the most extreme high tide events. The water flowed from Unit I through the culverts under Fowler Beach Road. Approximately 80 percent of Unit II can be classified as brackish marsh, while only about 20 percent is still fresh (located mostly on the southern side of the impoundment).

The continued influx of saltwater has killed approximately 80 percent of the freshwater vegetation. However, salt-tolerant vegetation is becoming established along the northern end of Unit II. In addition, some areas that are typically vegetated with freshwater species appear to have converted to open water. Due to the increased flow of water into Unit II through the inlets, more saline water than has been previously recorded is flowing into Unit III through the culvert under Prime Hook Road. Given the increasing levels of saltwater in Unit III, this freshwater marsh may convert to salt marsh.

Figure 2. Prime Hook NWR Dune Work Project Area



It is expected that even if the dune line is reconstructed and the inlets are filled, some portions of Unit II will continue to be highly saline and will not become freshwater due to the presence of highly saline water already in the unit and the occasional inundation of the area from Unit I during high tides.

In addition, it appears that the entire Prime Hook area is subsiding, i.e. sinking, although the causes and rate are not well understood. This may partly be a cumulative result of geologic factors exacerbated by anthropogenic factors (such as withdrawal of ground water for irrigation and domestic uses) and impeding opportunities for sediment replenishment, climate change, or other causes. Since both land subsidence and sea level rise are occurring concurrently in many locations, scientists often add the rates of both together and refer to this as the rate of "net sea level rise" or "relative sea level rise."

III. PURPOSE AND NEED FOR THE PREFERRED ALTERNATIVE

A. Purpose

The Service administers the National Wildlife Refuge System (Refuge System), which is world's largest collection of lands set aside specifically for the conservation and protection of wildlife and habitat and consists of 550 national wildlife refuges in all 50 states and several U.S. territories. The Service is the primary federal agency responsible for conserving, protecting and enhancing America's fish and wildlife populations and their habitats, including migratory birds and federally listed threatened and endangered species.

In 1997, the National Wildlife Refuge System Improvement Act was passed, which requires the Secretary of the Interior to maintain the biological integrity, diversity, and environmental health of the Refuge System. This law states that the mission of the Refuge System is:

> *"To administer a national network of lands and waters for the conservation, management, and where appropriate, restoration of the fish, wildlife, and plant resources and their habitats within the United States for the benefit of present and future generations of Americans."*

Service policy (601 FW 3) provides guidance on maintaining or restoring the biological integrity, diversity and environmental health of the Refuge System, including the protection of a broad spectrum of fish, wildlife and habitat resources found in refuge ecosystems. Refuge managers are provided with a process for evaluating the best management direction to prevent the additional degradation of environmental conditions and to restore lost or severely degraded environmental components. They accomplish this by assessing the current status of biological integrity, diversity, and environmental health on each refuge. Guidelines are also provided for dealing with external threats to the refuge and its habitats.

In the early 1960s, the southeastern coastal marshes of Delaware were under the threat of industrial development by oil refinery and manufacturing industries. To help preserve

those coastal wetlands, the refuge was established under the authority of the Migratory Bird Conservation Act (16 U.S.C. 715–715r) as amended on August 21, 1962, *"for use as an inviolate sanctuary, or for any other management purpose, for migratory birds."*

Refuge boundaries were later expanded to include 934 acres of land purchased with funding from the Land and Water Conservation Fund, under the authority of the Refuge Recreation Act (16 U.S.C. 460k–460k-4), as amended, for the following purposes: *"[land] suitable for (1) incidental fish and wildlife-oriented recreation development; (2) the protection of natural resources; and (3) for the conservation of endangered species."* The Refuge has acquired 10,133 acres comprised of 100 tracts ranging in size from 0.4 to 1,600 acres from 73 landowners.

The purpose of scraping overwash sediment to rebuild a dune/berm along Unit II and allowing the State to bring in additional sediment (the Proposed Action) is to re-establish some water management capability in Unit II, permitting time for rigorous monitoring of the system and development of a long-term restoration and management plan based upon the newly collected scientific information. As described in Part IV below, the Service has developed a marsh and water monitoring program, setting forth the scientific efforts to develop the specific information needed to craft its long-term restoration and management plan.

The Service announced in 2005 that it was initiating its CCP process. It is our intention to continue to develop the refuge's CCP, which will outline the multiple, large-scale and long-term factors that contribute to habitat management decisions over the next 15 years. The CCP will address impoundment and shoreline management in further detail, and will contain long-term strategies to manage habitat for wildlife consistently with national management policies while considering the impacts of that management to the surrounding community. This will provide time to analyze new information and to re-assess refuge management options through the CCP, which will be pursued as an Environmental Impact Statement (EIS), and post-CCP planning processes such as step-down planning.

Previous maintenance actions that moved sand bayward counteracted the natural processes that sustain dune systems in the face of storm events, sea level rise, and shoreline subsidence. Repeated continuation of these practices could further weaken the integrity of the dune and marsh system over time. However, given the degree of degradation of the current system, we are concerned that inaction in the short term may inadvertently increase the amount of open water in the impoundments and increase the challenges inherent in restoring the system's integrity, without the opportunity for a strategic restoration plan to be developed and implemented. Collection of additional data about the wetland system in its current state is vital. The EIS to be developed through the CCP process will provide the public a more comprehensive opportunity to address long-term management decisions. However, the Service is concerned that inaction in the short term, i.e. until the CCP is finalized, could cause the inlets to widen, increasing tidal flows and the break-up of the peat layer beneath the dead freshwater vegetation, so that restoration strategies—either to restore a freshwater or a saltwater marsh system—will be made far more difficult by conversion of the area to open water.

Salt marsh species are perennials, which develop thick mats of roots. As sea levels rise, if sufficient sediment is brought into a bay/back dune system, a salt marsh will grow at increasing elevations upon the matted roots and previously formed peat. If salt marsh vegetation is inundated by higher tide levels, these plants will die. The matted peat is a relatively robust material but, with repeated onslaughts of storms and tides, will break up; such areas generally become open water. Salt marsh restoration efforts have been successful in some situations by adding sediment to the peat layer. However, it is more difficult to restore a salt marsh after the peat layer has disintegrated. Freshwater marsh plants are annuals, which produce far larger quantities of leaf matter to root matter and grow in deeper waters. Thus, as long as saltwater can be kept out of a system, converting a salt marsh to freshwater marsh is relatively easy. Such artificially created freshwater marshes are vulnerable to a single storm event interjecting sufficient saltwater to kill the freshwater vegetation. Restoring a saltwater marsh from a freshwater marsh entails either being able to manipulate water levels to drain the area or introducing sufficient sediment to elevate it. Both of these require a solid understanding of the hydrological and other conditions of the specific area, information that is currently lacking for the Prime Hook NWR wetland complex.

Most barrier dune systems respond to storms and sea level rise through a process known as "barrier island roll-over." Without human manipulation, a barrier beach does not remain in the same alignment when there is an insufficient supply of sand; instead, it sustains itself by moving landward, thereby buffering salt marshes on the interior. In places where barrier islands are artificially maintained in fixed alignments, barrier islands tend to narrow, providing less width for upland vegetation, which can anchor the sand. Salt marshes are very sensitive to water levels and if they cannot maintain their elevation, marsh vegetation dies, the peat layer beneath crumbles and breaks apart, and the amount of open water increases. To maintain the health of the interior system, a steady supply of sediment is needed, which is carried into the interior system through inlets and across barriers by high water events. Even if the barrier is not interrupted by an inlet, cross-island overwash events move sediments into the interior, which are then reworked by the tides to increase salt marsh elevation. If a barrier island is subject to erosion along its outer face, and marshes along its interior shore disintegrate, the barrier system then is subject to increased lowering and disintegration. This is already occurring in barrier systems along the southeast Atlantic and Gulf Coasts (Climate Change Science Program 2009).

Given our increased knowledge concerning marsh and barrier systems, and the increased challenges to sustain these systems in light of sea level rise and surface subsidence, we now understand that converting salt marsh to freshwater impoundments in 1988, and the subsequent dune line maintenance, however well-intentioned, probably exacerbated the problems we confront today. However, at present, the optimal restoration plan for the entire system is not immediately clear, and there is enough uncertainty regarding how the system will respond to rapidly changing conditions to warrant further study and consideration. We know that we need to conduct additional monitoring to better understand the current conditions and some time to develop an optimal and sustainable restoration plan for these units. We also know that if the peat layers disintegrate over the

short term, our restoration options will be far more limited and the potential for restoring any marsh habitat may be lost.

National wildlife refuge management policies emphasize the need to examine the historic functioning of natural ecosystems prior to substantial human-related changes to the landscape, and direct us to restore the biological integrity, diversity, and environmental health of the natural systems we manage. The evaluation of Units II and III in the CCP will include an examination of maintenance costs in relation to habitat management benefits. An understanding of local subsidence will be developed from current road, water control structure, and dike elevations relative to mean sea level (msl), and associated elevational changes since 1987. Estimated marsh accretion rates from radiometric data (^{210}Pb and ^{137}Cs substrate core samples) collected by the DNREC's Coastal Program in 2009 and 2010 will be incorporated. Costs associated with managing the impoundments, which will likely include raising State roads that are used as dikes, annual soft armoring of the dune line, and repairing and raising water control structures will also be presented. This analysis will be used to propose and support future decisions regarding impoundment and shoreline management objectives. Alternatives which incorporate restoration of naturally sustainable habitats, such as restoring the historic salt marshes, and for freshwater wetland habitats will be examined in light of sea level rise and other climate change. Low-lying adjacent areas now managed as upland were former wetlands and may be appropriate to evaluate for future adaptation to freshwater impoundments. Costs and the likelihood of success of all future management schemes will be analyzed.

Public concerns have been raised about access to the Primehook Beach community via Prime Hook Road, which has recently been impassible more frequently under high water conditions. This road, as well as Fowler Beach Road, is located on refuge lands and the State holds an easement to construct and maintain them. Both roads were built on salt marsh and neither was constructed to withstand flooding or subsidence. These roads act as dikes and can slow the volume of water flowing into the interior during normal tidal conditions and impede the drainage of water out of the system from large storms. The high water access problem could be addressed by constructing a causeway or elevating the road, but such options require significantly more planning between the Service and the Delaware Department of Transportation (DelDOT). Additionally, funding for a project of that nature would need to be secured.

Much of the sand that will be used to reconstruct the artificial dunes as proposed now rests on federal lands. The project as currently proposed will build an artificial dune/berm substantially landward of its earlier location. This is consistent with the natural process of "barrier island roll-over." While some sand will be moved from federal land onto private land and federal resources generally cannot be used to enhance private lands, this action is needed to benefit the refuge. To be clear, the State of Delaware will finance all work on private lands. This project is proposed as a short-term effort to maintain the status quo and to allow the refuge time to determine the optimal restoration approach to sustain long-term habitat integrity of the refuge. The benefit to the government is the re-establishment of management capability for the benefit of wildlife, at least for the short term, and the

opportunity to collect vital data about the wetland system in its current state for the CCP EIS that will guide management for the long term.

The action proposed may have the incidental effect of reducing flooding or erosion within the system. However, since there have not been sufficient hydrological studies conducted to date, it is not clear that the project will necessarily reduce flooding in the Prime Hook area. In some estuaries, depending upon the land area draining into a marsh system, flooding can be exacerbated when there are insufficient outlets through the barrier beach system for an area to drain after large storms. The hydrology of the larger drainage area is one of the topics to be examined in greater detail.

While some of the public comments favoring Alternative 2 reflect the perception that the Proposed Action will help protect adjacent private lands and development from marsh-side flooding, the purpose of this project is not to protect or to encourage private development. In fact, without more careful hydrological analyses, it is unclear whether, given the existing pattern of dikes, roads, and other alterations to this system, storm-related flooding might actually be exacerbated because the inlets may both facilitate drainage of floodwaters as well as allow the influx of water from high tides.

The Service is disinclined to choose the No Action Alternative because we have not yet developed a final management approach, which will be accomplished in the developing CCP to be released this winter. For the short term the Service has a clear need to repair the Unit II dune. Therefore, we believe it is prudent to consider the proposed dune work through this EA, as needed, in the short term until final determinations are made regarding long-term management through the CCP/EIS process.

B. Project Location

Prime Hook NWR is located in Sussex County, Delaware (Figure 1). Refuge lands involved in this project are located along the Delaware Bay between the end of Fowler Beach Road and the Primehook Beach community to the south. Approximately 700 linear feet of the barrier island located immediately south of Fowler Beach Road is owned by the refuge and the remainder is on private lands. All marsh areas below mean low water behind (west of) the barrier island are part of the refuge. The project location involves a complex patchwork of refuge and private ownership (Figure 2). The refuge's approved acquisition boundary includes all of the privately owned parcels on the barrier island within its authorized acquisition boundary. It is the Service's policy and goal to eventually acquire the 3,200 linear feet of private lands when and if the landowners are willing to sell.

C. Decision To Be Made

The Final EA identifies Alternative 2 as the Service-preferred alternative. This is the alternative the refuge manager feels would best meet the purpose of and need for the project. Specifically, in the professional judgment of the refuge manager, Alternative 2 represents the suite of actions that best supports project goals and addresses issues concerning management of Prime Hook NWR.

Our regional director will make the final determination of what actions will be implemented. This final decision will be based on his review of the alternatives and their impacts as described in the Final EA, including any mitigation measures to minimize negative environmental effects on soils and coastal sediment resources, vegetation, migratory birds and other wildlife, invertebrates, and cultural and historical resources. The regional director, in making his decision, can select any of the alternatives evaluated in the Final EA, or he can select a combination of the actions or alternatives evaluated. The rationale for his decision will be made in the Finding of No Significant Impact.

D. Public Involvement

The refuge manager and State officials have attended several meetings with other involved agencies (DNREC, DelDOT, the U.S. Department of Agriculture Natural Resources Conservation Service) and local and State politicians, and have responded to many written inquiries regarding public concerns related to refuge shoreline management issues. The Proposed Action has been developed in consultation with our State partners and in consideration of requests for action by the public. This EA was available for public review and comment for 30 days. As described in more detail in Part VI, the Service held a public meeting and received 46 letters or other written comments from members of the public and government agencies.

The final EA reflects changes in the Proposed Action as a result of public input. Three commenters supported Alternative 1. A total of 33 commenters supported Alternatives 2, 3, or a combination of both. The three commenters who supported Alternative 1 generally supported allowing natural barrier island processes to occur without constraint or human manipulation. The decision to modify the alignment of the dune/berm form to be as far landward as possible mimics the process of barrier island roll-over while reducing the risk of disintegration of the marsh substrate.

E. Coastal Beach and Shoreline Management Issues

Coastal beach and shoreline management issues are influenced by important factors, including:

- Local geologic framework of the refuge,
- Physical processes (sea level rise, storms, subsidence, extreme wind and waves),
- Sediment processes and supply,
- Human activity, and
- Climate change and sea level rise impacts.

Human activities that attempt to slow beach erosion with the construction of groins, jetties, and repetitive sand replacement (beach nourishment) projects overwhelm and mask natural responses and physical processes that shape and sustain barrier island shorelines and associated marshes (Riggs et al. 2009). When barrier beach island shorelines are armored against erosion, they cannot evolve as they would naturally, and erosion and breaching of natural areas adjacent to developed shorelines is accelerated.

Coastal habitats are part of a complex system consisting of more than just beach, and while shoreline erosion threatens property near or on the coast, it can also profoundly influence marshes behind the beach (Northeast Climate Impacts Assessment [NECIA] 2007). For example, overwash development from storm activity is an important mechanism for moving sediment into the back-barrier and associated wetlands, maintaining the ecological integrity of barrier island and sandy beach habitats. This process is prevented when shorelines are armored, regardless of the use of hard or soft techniques (Defeo et al. 2009; NECIA 2007).

Current rates of sea level rise and climate change are already having profound effects on coastal ecosystems. However, as a direct effect of either destroying and/or armoring shoreline habitats by human activity throughout the United States, coastal beach habitats are being degraded by human-caused alterations to the coastal environment to an even greater extent than negative impacts from sea level rise and climate change (Coch 2009; Neal et al. 2007; Riggs et al. 2009; Titus et al. 2009).

Barrier beach inlet formation can be inappropriately labeled as the only cause of flooding of private property during storm events. Yet there are many other extenuating causes and effects involved. Physical forces that affect coastal beach flooding include increased storms and storm intensities, heavier precipitation patterns, extreme wind and wave conditions, extensive runoff from uplands, especially given regional increases in impervious surfaces, low elevation of roads and private properties with respect to local mean sea level, local geologic features, sediment supply, and human activities. Depending upon the hydrology and extent of the upland areas draining into a marsh system, a shortage of inlets or overwash areas due to diking and reinforcement of the barrier island can also contribute to bayside flooding by impeding drainage during and after storms. These factors increase the level of complexity of coastal flooding seen at the refuge and on adjacent private lands.

For example, a summary of the data collected at the Lewes tide gauge illustrates that the number of times water levels exceed “mean higher high water” (MHHW) and, more importantly, instances of consecutive tides above MHHW, have been increasing in frequency and duration over recent decades (http://www.tidesandcurrents.noaa.gov; Figure 3). When refuge impoundments were established in the late 1980s, there were typically 10 to 20 instances per year of consecutive tides above MHHW. By the 2000s, there were typically 15 to 25 such events per year. In 2009, there were over 30 events. This pattern is likely exacerbating any coastal flooding that the area around the refuge has experienced historically. As another example, instances of coastal flood warnings issued by the National Weather Service for the area have increased and coincide with events of consecutive tidal events above MHHW (Figure 4).

Figure 3. Number of Events of Consecutive (2 or more) High Tides above MHHW per Year Recorded at the Lewes, DE, Tide Gauge

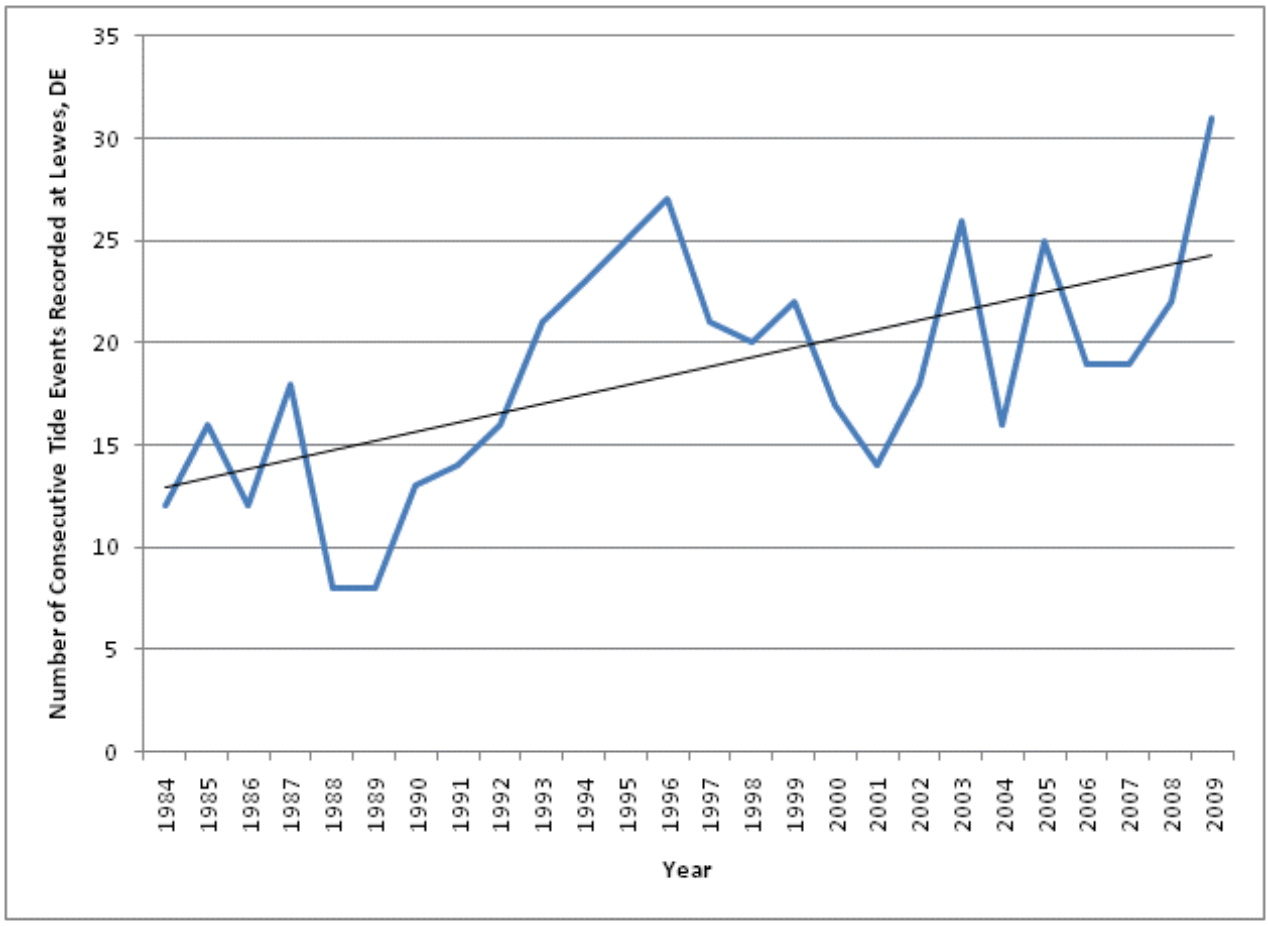
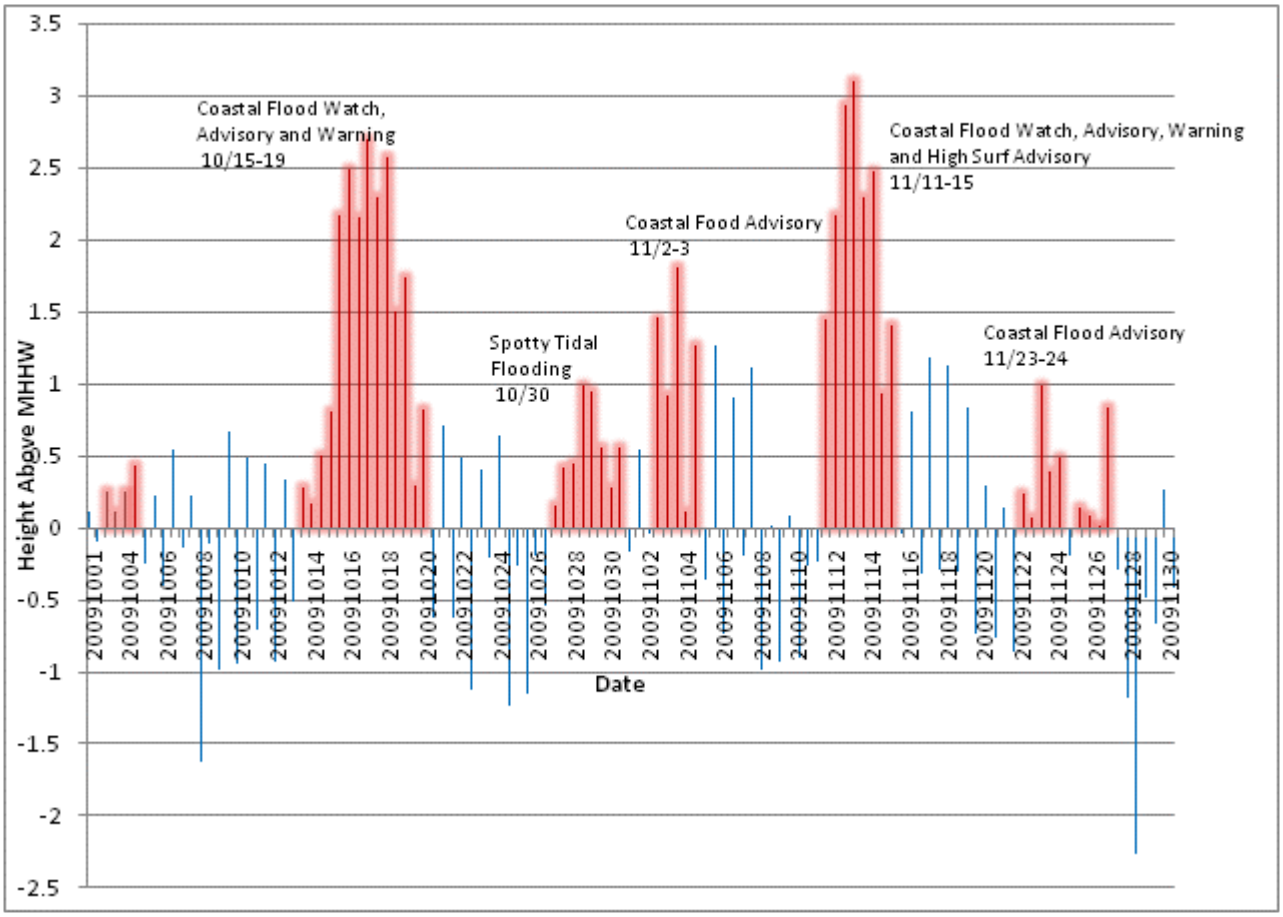


Figure 4. Consecutive High Tide Events Above MHHW During October – November 2009.



The Climate Change Science Program (CCSP) report (2009) states that increased sea level rise rates will raise groundwater tables and increase surface water levels. This will significantly slow the rate at which coastal areas can drain, with drainage being further exacerbated by increased flooding effects from rainstorms and prolonged flooding of coastal environments after a storm passes through. As a result, roads below one meter elevation can expect to remain submerged for longer periods of time in these coastal zones.

Current dominant public perceptions are that the only solution to storm flooding is a static engineered response of holding the shoreline in a permanent position. This may be one solution to protect private beach property; however, it may not be a viable solution for managing beach habitats and back-barrier wetlands for coastal wildlife, nor are climate scientists projecting that this approach will be sustainable given even modest projections for sea level rise (CCSP 2009). Refuge shorelines will continue to be impacted by climate change, mostly through increased rates of local sea level rise and changes to storm tracks, frequency, and intensity.

In the past, shoreline management was not an issue for the refuge and passive management of shorelines, that is, nature taking its course, was the general philosophy from 1963 to 1987. However, present climatic conditions, coupled with relative sea level rise rates, force us to review this management approach. Environmental conditions of the refuge's coastal habitats have rapidly changed over recent years, believed to be due at least in part to increased sea level rise effects, possible subsidence of local and regional land forms, suspected subsidence of local roads, more severe and frequent storm effects, and prolonged frequency and duration of flooding.

These changes have moved shoreline management to the forefront of refuge management concerns. This has necessitated the short-term remedy recommended by the Proposed Action, which will provide some time to analyze new information and to reassess refuge management options through the CCP and post-CCP planning process. The Service must now assess beach and wetland sustainability within a very different climatic and physical environment than was experienced when current management regimes were established, also recognizing that well-intentioned past refuge management may have created unexpected degradation and instability in the system.

IV. ALTERNATIVES

A. Summary of the Alternatives

The Draft EA proposed an Action Alternative with two other reasonable alternatives in comparative form, defining the differences between each alternative, and providing a basis for choice among options by the decision maker. Each alternative was further evaluated by comparing environmental consequences. The initially proposed alternatives were:

- Alternative 1 (No Action)
- Alternative 2 (Preferred Alternative): Short-term soft dune line reconstruction using sand scraped on-site
- Alternative 3: Dune line reconstruction using material from off-site sources

Based upon public and other agency comments and review of the current site conditions, the Service has decided to propose to implement a combination of Alternative 2 and Alternative 3. The location of Alternative 2 has been modified by placing the dune/berm as far landward as possible, which is both on refuge and private land (Figure 5). Work will be consistent with conditions set by the State of Delaware. Alternative 3 will be utilized by the State of Delaware should it determine that additional sand is needed above the quantities that will be reconfigured under Alternative 2 and as funding is available.

Figure 5. Map of project area, showing private land and approximate planned location of dune/berm to be constructed. Boundaries and dune/berm line location are for reference only and are not suitable for legal or survey purposes. (Data – USFWS; Imagery – Google)

B. Description of Alternatives

1. Alternative 1 (No Action). This alternative would allow the existing overwashes to continue to build, and would allow regular tidal flow into Unit II. No dune lines would be repaired.

   This alternative would have:

   - Allowed overwash and inlet formations to remain intact with the natural dune lines transgressing and forming on their own and re-establishing tidal flow into back-barrier marshes.
   - Expected that inlets would form and reseal themselves and that washover areas would fluctuate in size and location as the ecosystem self-adjusted in response to various factors and physical processes (e.g., relative sea level rise, recurrent storm history, wave dynamics, local and regional subsidence rates, sediment supply, and legacy effects from human activities).
   - Permitted natural conversion of a manmade freshwater system back to a brackish or salt marsh system or open water.

2. Alternative 2 (Preferred Alternative). The Preferred Alternative, which is the Proposed Action, involves reconstruction of approximately 950 feet of dune/berm on refuge land using on-site sediments on an interim basis until the CCP is finalized (Figure 5). Those sediments would be used to repair dunes both on and off the refuge. Off-refuge lands involved in the project include approximately 2,000 feet of a 3,200-foot-long dune line on private lands within the approved refuge boundary held by three individual landowners. The State would conduct dune repair work on the dune line on private land. A partner non-governmental organization is working on behalf of the Service to negotiate with willing sellers to purchase these lands for future inclusion in the refuge. In addition, newly created inlets south of Fowler Beach Road will also be filled. Due to the dynamics of the system, it is likely that a portion of the sediments used for this project originated on both refuge and private lands before being relocated by the overwash process.

   The Proposed Action would:

   - Re-establish dune lines on refuge lands utilizing existing sand on the landward side, with the purpose of joining this dune/berm to any remaining dunes on private lands. The alignment of this dune/berm will be as far landward as possible, given the constraints of the site and conditions required by the State of Delaware.
     - The resulting refuge dune/berm may be approximately 950-feet-long, 100-feet-wide at the base, and 5.2-feet-high NAVD (North American Vertical Datum), with a 10:1 slope on east and 8:1 slope on the west side. The entire project would be 2,950-feet-long, 100-feet-wide at the base and 5.2-feet-high NAVD.
     - The size of the dune will be limited by available sand (a base must remain in place to support the weight of the equipment).

    - The estimated volume of sand needed for the project ranges between 364,000 and 494,000 cubic feet on refuge land to approximately 1,040,000 cubic feet on private land. It should be noted that portions of the berm may reside on both refuge and private land. Volumes are estimates only. Due to the dynamic nature of barrier island tides and storm events, volumes are never constant.
    - A layer of sand sufficient to support the weight of the equipment would be left in place. No sand will be removed below the 2.2-foot NAVD (North American Vertical Datum) level. Mean high water is 1.9-foot NAVD. DNREC's Shoreline Division surveyed the first inlet south of Fowler Beach Road.
- Close recently formed inlets south of Fowler Beach Road.
- Allow sand that has likely washed onto the refuge to be moved back onto higher elevations of refuge land, and partially onto private land.
- Only be conducted if the entire dune along Unit II, including portions on private land, is slated for reconstruction.
- Include pre- and post-work shoreline profiles to document the conditions and quantities of material to be reconfigured.
- Take approximately two to three weeks to complete, weather permitting.
- Not involve the use of federal funds to perform work on private lands. The estimated project cost is $13,000 to $19,000.
    - Construction costs are $125-$150 per hour, depending on equipment involved.
    - Mobilization and de-mobilization will cost approximately $1,000.
- Be completed between August 15 and March 1.
- Be subject to revision as required in permits from the U.S. Army Corps of Engineers and DNREC.

The DNREC will serve as the cooperating agency and partner of the Service to complete the Proposed Action on both private and Service lands. The Service has been working closely with them throughout the planning process. The SWMS of DNREC has jurisdiction for implementing the State's Beach Preservation Act by issuing coastal construction permits for beach scraping. It also has the specialized expertise to conduct refuge dune work. Delaware's Coastal Program reviews the consistency of federal actions with State coastal policies under the Coastal Zone Management Act. SWMS will also facilitate and coordinate the linkage between refuge land and private land dune reconstruction, and coordinate with private landowners involved in the project. The refuge will revegetate the dunes with American beachgrass (*Ammophila breviligulata*) as part of the restoration prior to the growing season following the work.

Concurrently, the Service will develop protocols and contract specifications/proposals for scientific investigations that will be initiated or continued to improve our understanding of the local system. These ongoing and proposed studies, which will occur over at least a five-year-long period, will be conducted in conjunction with State and federal partners, and will characterize and monitor a number of variables critical to the understanding of this complex system. Current and proposed scientific

monitoring and studies regarding the impoundment wetland system are summarized below:

- To date, the refuge has acquired data regarding elevations of the marsh surface along repeatable transects, at the water control structures, and along the State-owned roads that form impoundment dikes. These measured elevations will be compared to the planned construction elevation (in the case of the water control structures and roads), and with tidal data such as MHHW.
- Surface elevation tables (SET) will be used to monitor current and future marsh accretion within refuge wetlands. Sediment cores will be analyzed to further quantify historic accretion rates. Marsh accretion rates will be examined in relation to current and projected sea level rise rates, as well as in response to management actions.
- Utilizing National Park Service protocols, and coordinating closely with similar work already conducted by DNREC, the refuge proposes to characterize the changing coastline position and profile topography twice annually. This monitoring will help improve understanding regarding the gains and losses of sediment along the Delaware Bay shoreline.
- A network of real-time monitoring stations will be established throughout the wetland complex, measuring variables such as water level, salinity, pH, temperature, and dissolved oxygen. These parameters will enhance understanding of the movement of water within the wetland complex in response to tidal changes and storm events.
- Transect sampling will be used to characterize the reach of the saltwater prism into adjacent freshwater creeks.
- Sampling protocols will be developed to quantify suspended sediment concentration and selected nutrients (ammonium, nitrate and nitrite, ortho-phosphorus, dissolved nitrogen and phosphorous, and chlorophyll A) from key locations throughout the wetland units. Sampling will be conducted following storm events, as well as under normal conditions.
- In cooperation with the University of Delaware and DNREC, we participate in research to estimate current behavioral use and food availability for dabbling ducks during winter and migration in impoundments and adjacent tidal wetlands. We are working to expand this research to include other waterbird groups, such as shorebirds. These findings will help us better understand how migratory birds may respond to changing wetland conditions on the refuge and elsewhere.

It may take several years to collect and analyze enough data to develop sufficient understanding of the system to fully refine future management plans. This comprehensive monitoring program will enable us to further define management needs in response to the changing environment, to evaluate management approaches, and revise or adapt restoration actions in light of the system response. Our ultimate goal will be to develop a management plan that will best establish the means and measures by which the long-term conservation of the refuge's fish, wildlife, and other natural resources may be achieved.

3. Alternative 3. The same dune line repairs and filling of existing inlets would occur; however, no sand would be scraped from refuge lands to complete the work. All materials needed to complete work on refuge lands would be hauled from off-site sources. Additionally, no materials existing on refuge lands would be scraped to reconstruct dunes and fill inlets on private lands.

   This alternative would:

   - Re-establish dune lines on refuge lands utilizing sand hauled from off-site sources. The estimated cost of material is $47,000 to $78,000 (based on $15 per cubic yard). This does not include anticipated road repair costs.
   - Fill inlets south of Fowler Beach Road with sand from off-site sources.
   - Not utilize existing on-site sediment from refuge washover areas.
   - Not permit the use of refuge sediments for repairs on private property. Construction partners would be permitted to access refuge property to complete work on private property.
   - Only be conducted if the entire dune line along Unit II, including portions on private land, are slated for reconstruction.
   - Take approximately two to three weeks to complete, depending on weather and material availability.

   As in the Preferred Alternative, the Service would work closely with our partners at DNREC, along with neighboring private landowners.

C. Alternatives Considered But Not Studied in Detail

1. Elevate Prime Hook Road. Community concerns regarding interrupted access and impaired emergency evacuation and response could be permanently alleviated if the State elevated Prime Hook Road. That route is the only road leading in and out of the Primehook Beach community, a private community of about 206 homes or landowners (as of 2004). One alternative would be to elevate the road on a causeway, which would not impair tidal flushing. If an elevated dike is utilized, it must be designed with sufficiently large conduits and/bridges to prevent obstruction of sediments and nutrients. Any road work planning and construction would be coordinated with Service personnel.

2. Avoid use of overwash sediments to reconstruct the dunes. In some communities, beachfront sediments or sand from the intertidal zone are used as a source for dune enhancement. The State of Delaware has determined that there is insufficient sediment to remove sand from the beachfront; therefore, this option will not be permitted by the State.

3. Only use ‘federal sand’ to restore overwash areas on federal lands. Insufficient quantities of sand remain on private lands adjacent to the project site to restrict the use of ‘federal sand’ to only federal property. The only practical option is to follow Alternative 3, which is substantially more costly and may be very difficult to implement given the condition of Fowler Beach Road. Refuge lands are immediately

behind private lands. This sand has previously rested on private land, although given the history of dune manipulation, it may have moved back and forth several times. The justification here, as explained above, is that this short-term action will help preserve the federal marshlands and waters of the interior wetland system, preventing rapid conversion to open water, until a long-term restoration program is implemented through the CCP process.

4. Dredge sand from off-shore and pump it onto the beach. This alternative is completely cost prohibitive at this time.

V. AFFECTED ENVIRONMENT AND ENVIRONMENTAL CONSEQUENCES

This section describes the affected environment and environmental consequences that considered alternatives would have within the project area, if implemented. It summarizes the physical, biological, historic and cultural environments of the affected project area and the potential changes to those environments due to implementation of each alternative action. This section also examines the environmental effects from past and present actions, and reasonably foreseeable future actions in the face of the changing environment and accelerated sea level rise.

A. Impacts on Soils and Coastal Sediment Budgets

1. Affected Environment

Project site soils are mostly sand, marsh mud, and marine sediments. Regional sediment plans developed by the U.S. Army Corps of Engineers (2004) in the Northeast recognize sand as a vital natural resource and that sand and marine sediment processes are critical components of coastal barrier islands, sandy beach, and associated salt marsh ecosystems. To understand the environmental consequences of the alternatives in this EA, the geologic framework of the refuge and the surrounding area that influences the physical functioning of the affected environment merits further examination.

Delaware is located on the flank of the Baltimore Trough Geosyncline, a massive downfold of the Earth's crust, filled with sediments. The relative instability of this crust is the primary cause of local subsidence of the area. Delaware's coastal zone is a low-lying coastal plain and part of a larger geological structure known as the Atlantic coastal plain/continental shelf. Its shorelines are migrating rapidly in geologic time, in a landward direction. This is caused by several geological and physical processes (Kraft et al. 1976):

- Subsidence or sinking of the continental shelf and Atlantic coastal plain.
- Sea level rise relative to the land.
- Erosion and redistribution of sand and marine sediments in the coastal zone, known as littoral drift, or the transport and redistribution of sand in the littoral zone under the influence of waves, tides, and currents.

- Dynamic position shifting of shorelines as they migrate landward and upward, known as marine transgression or barrier island roll-over, in response to sea level rise, storm activity and changing weather patterns as the main driving forces.

Scientists have subdivided the immediate coastal zone of Delaware into six zones based on local geomorphic features and lithology (Kraft et al. 1976). It has been estimated that approximately 450,000 cubic yards of sand move by any one point on the coast during an average year (Turner 1968). For this massive flow of sand to occur, coastal erosion must take place in some areas while sand accretes in others. In general, the net littoral drift, or flow of sand, in the surf zone is northward along the Delaware shoreline. From time to time the average littoral drift shifts southward around Bethany Beach. This shift of the point or loci of change between northerly and southerly flows is not fully understood (Kraft et al. 1976). Additional study of the off-shore dynamics is needed before the local system is well understood.

Littoral drift flows in the Delaware Bay are even more complex. Tidal flow floods seawater into the bay in high arcs, sweeping around then turning and ebbing back along the shoreline. For this reason, the dominant littoral drift from Broadkill Beach south into Lewes is southeast. However, littoral drift is not fully understood in terms of direction or magnitude on the smaller beaches or shoreline areas of the bay.

Strong littoral drift flows also have the effect of accreting or eroding back-barrier marshes. Geological evidence indicates the present area covered by the Great Marsh in Lewes and the Primehook marshes was coastal lagoon in the near past (i.e., about 500 years ago) demonstrating how open water areas with significant sediment accretion rates can evolve into marsh systems. These two areas may be well-positioned along the lower mouth of the bay to receive sediment during northeast storm events (Kraft et al. 1976; Steveson and Kearney 2009).

Refuge sandy beach and shoreline habitats are located in a geomorphic zone which starts at the upland surface at Bower's Beach southward to the area of the Great Marsh in Lewes to the Roosevelt Inlet, and is one in which the littoral drift of sand is in fairly continuous motion. This zone is characterized by areas of broad coastal marsh separated from the waters of the Delaware Bay by a continuous ribbon of a narrow band of sandy coastal barrier island beach. Most of these "ribbons of sand" are rarely higher than eight to ten feet and range from five to several hundred-feet-wide (Kraft et al. 1976).

Another characteristic of the geomorphic zone of the refuge is the rapid erosion and landward migration of these ribbons of sand at rates of up to 10 feet per year or more. Erosion rates vary throughout particular segments of barrier beach based on local geomorphological features and human activities. The entire coastal zone of the Delaware Bay is unstable and subject to sediment compaction, tectonic subsidence and relative sea level rise with average rates of erosion continuing or accelerating into the future along a very low-lying Atlantic coastal plain setting in relation to mean sea level (Kraft et al. 1976).

During spring tides and storms, sand is easily washed across barrier islands and into marsh areas. Although the sediment supply along the western shore of the bay is less than the Atlantic transport, there is a sufficient supply of sand and gravel to maintain a continuous estuarine washover barrier. Washover fans, broad marshes, inlets, tidal creeks, and diverted river channels such as the Broadkill River extend from washover barrier beaches on the upland areas with Pleistocene sediments characteristic of the Delmarva Peninsula (Kraft et al. 1976).

The shoreline segment south of Slaughter Beach to Primehook Beach is characterized by a continuous estuarine saline fringe and washover barrier with broad marshes containing Holocene muds about 10-feet-thick (Kraft et al. 1976). Fowler Beach is typical of this shoreline type, with Pleistocene sands and gravels of Slaughter Neck continuing into the shallow subsurface beneath Fowler Beach. Draper Inlet and Slaughter Creek were tidal drainages flowing through Slaughter Neck into the bay during the 18th and 19th centuries, which were later sealed by sediment transport processes and are no longer directly connected to the bay (Stauss 1980).

2. Environmental Consequences

   a. Alternative 1 (No Action)

      If the No Action Alternative were implemented, regular tidal flow would continue to enter Unit II through the newly formed inlets. "Elevation capital" accrued through recent overwash events would likely move to back-barrier environments as shorelines continue to naturally transgress landward. Tidal flow would become more completely re-established, reverting impounded marshes back to a brackish and ultimately a saline environment. In the long run, these conditions may enable the marsh to better keep up with sea level rise, as the effects of "storm sedimentation" could aid in the vertical accretion of these marshes. Alternatively, at least some areas could be converted to open water if collapsed peat sediment can not readily support natural revegetation.

      This alternative may begin to improve the current low rate of sediment accretion. Analysis of sediment cores for the presence of radioisotope fallout (^{137}Cs and ^{210}Pb) deposited at a known time in the past can provide a measure of accretion over recent decades. Preliminary data from radiometric coring conducted by DNREC's Coastal Program indicates that Unit II marshes have not been keeping up with current sea level rise rates over the last 50 years (DNREC 2010, unpublished data). Marsh accretion rates were spatially and temporally variable, and dependent to a large degree on storm-dominated sediment dynamics and overwash processes to supply sediment to coastal marsh and barrier beach systems (Aubrey and Speer 1985; Leatherman and Zaremba 1986; Roman et al. 1997).

      Washover and inlet formation can potentially contribute to the sediment budget of the refuge's sandy beach and marsh environments in the long term. Washover is a major process in the retreat mechanism of coastal barrier beaches in response to

sea level rise (Dillon 1970; Kraft et al. 1973; Kraft et al. 1976). Alternately, there remains a recognized lack of understanding regarding the interactions among changes in wetland elevation, sea level, and wetland flooding patterns, and changes in other sediment accretion drivers, such as nutrient supply, sulfate respiration, and soil organic matter accumulation (CCSP 2009). Human-altered drainage patterns, as exist in the refuge impoundments, appear to be limiting the vertical accretion of sediment, at least in Unit II. In such cases, rapid saltwater intrusion into the unit could potentially cause subsidence through collapse of organic soils and conversion to open water (DeLuane et al. 1994; Pearsall and Poulter 2005). Too rapid a conversion of the former marsh system may cause unanticipated biochemical results, which has led marsh restoration experts to advise that tidal restoration programs be conducted gradually (Portnoy and Giblin 1997).

b. Alternative 2 (Proposed Action)

If the Proposed Action Alternative were implemented, marine transgression of the shoreline would be temporarily halted, as it had been between the late 1980s and through the fall of 2009. The marsh system behind the dune line would contain less sediment than is now present due to the scraping activities associated with dune reconstruction and inlet filling. Artificially stabilizing the dune line may result in the temporary loss of washover sediments from nearshore sources.

In the short term, it is expected that the beach system will once again re-position the dune line to a new equilibrium point in response to daily tidal action and effects of storm activities. Conducting the Proposed Action work after August 15 may allow some onshore transport to bring more sand to the beach face during calm conditions, offsetting sediment deficits from winter months when large waves move sand from the beach to the offshore zone, thereby providing more sand to rebuild dune lines. Often in coastal storms, a beach can lose several hundred feet of sand, and then in the following weeks regain some of that sand (Pratt 2009).

Dolan and Godfrey (1973) demonstrated that sandy beach and marsh ecosystems can have reduced sediment budgets due to artificial dunes. They compared the response of a stabilized dune line (dunes artificially built up to sufficient height to restrict overwash) to an unstabilized barrier beach dune line and evaluated both responses to a hurricane. Although the unstabilized dune lines were overwashed, by lowering the natural dune crest and moving it landward, this section of the shoreline maintained a broader beach. In contrast, the stabilized shoreline lost most of its beach sediments to offshore environments. Also, shifting sand from one location to another on the same beach offers little to no effective solution to coastal erosion and flooding of beach properties and at best is only a temporary fix because barrier migration or roll-over is inevitable unless dunes are continually rebuilt (Coch 2009; DNREC 2004; DNREC Secretary's Order No. 2009-W-0048; Levine et al. 2009; Pilkey and Young 2009; Riggs et al. 2009).

The monitoring and research activities proposed will begin to address data gaps associated with the physical soil and sediment condition within the highly altered and manipulated impoundment wetland complex. Such data will serve to reduce uncertainty regarding the system's likely response to changing conditions in the future, which might then be better managed to ensure a favorable outcome.

c. Alternative 3

If Alternative 3 were implemented, environmental consequences related to the flow of tidal waters and deposition of sediments would be similar to Alternative 1. However, recently deposited washover sediments would remain within Unit II and might aid the establishment of marshland behind the constructed dune line.

Sand placed on the project site must be similar in character to the sand naturally occurring on the beach. When using sand from off-site sources, it is important to consider the appropriate grain size for each specific project. Characterizations of sand from the project area can be achieved by conducting an analysis to determine the grain size of sand needed, and to avoid sand particles that are too small which tend to be transported in suspension when overwashed with water (Wanless 2009). Improper sand sources (incorrect sediment grain size) could have adverse impacts on piping plover or horseshoe crab habitats. The SWMS has successfully conducted beach nourishment projects hauling sand from off-site sources to project sites that successfully create suitable habitat for horseshoe crabs and piping plovers (DNREC 2004). Refuge staff would work with SWMS to ensure proper sand size was obtained for this project.

B. Impacts on Vegetation

1. Affected Environment

Vegetation usually colonizes newly formed overwash habitats, and new dune growth is subsequently initiated. Due to the dynamic nature of constantly shifting sands, only a limited number of plant species are suited to this environment. The current overwashes are generally not vegetated because they are in an early stage of development. However, as several growing seasons pass, sea rocket (*Cakile edentula*) would be the first plant to pioneer the site. It typically sprouts in the wrack line. Other plants that colonize bare sand include beach pea (*Lathyrus japonica*), seaside spurge (*Euphorbia polygonifolia*), glasswort (*Salicornia* sp.), beach heather (*Hudsonia tomentosa*), and American beachgrass (*Ammophila breviligulata*). Nor'easter events and storm surges can wash in giant reed (*Phragmites australis*) rhizome remnants, which if long enough (greater than eight inches) can remain viable and colonize dune areas. American beachgrass and overwash dune grassland communities of the mid-Atlantic are considered rare. Many of the highest quality occurrences are on public land (NatureServe Report 2006).

Overwash dune grassland habitat is restricted to storm-generated overwash areas of maritime dune systems. It is typically small in extent and not usually more than a

few acres in size. It is best developed on barrier islands of Delaware, Maryland, Virginia, and North Carolina. As part of a very dynamic system, this community is extremely ephemeral, buried by sand deposition over time and/or appearing in newly formed overwashes in other areas subjected to storm-energy forces. Because of the dynamic forces structuring this vegetation community, it requires sufficient area to accommodate the constantly shifting mosaic. The community is restricted to a specialized habitat and is threatened by a number of human activities, including shoreline armoring, artificial dune stabilization, and trampling by off-road vehicle use (NatureServe Report 2006).

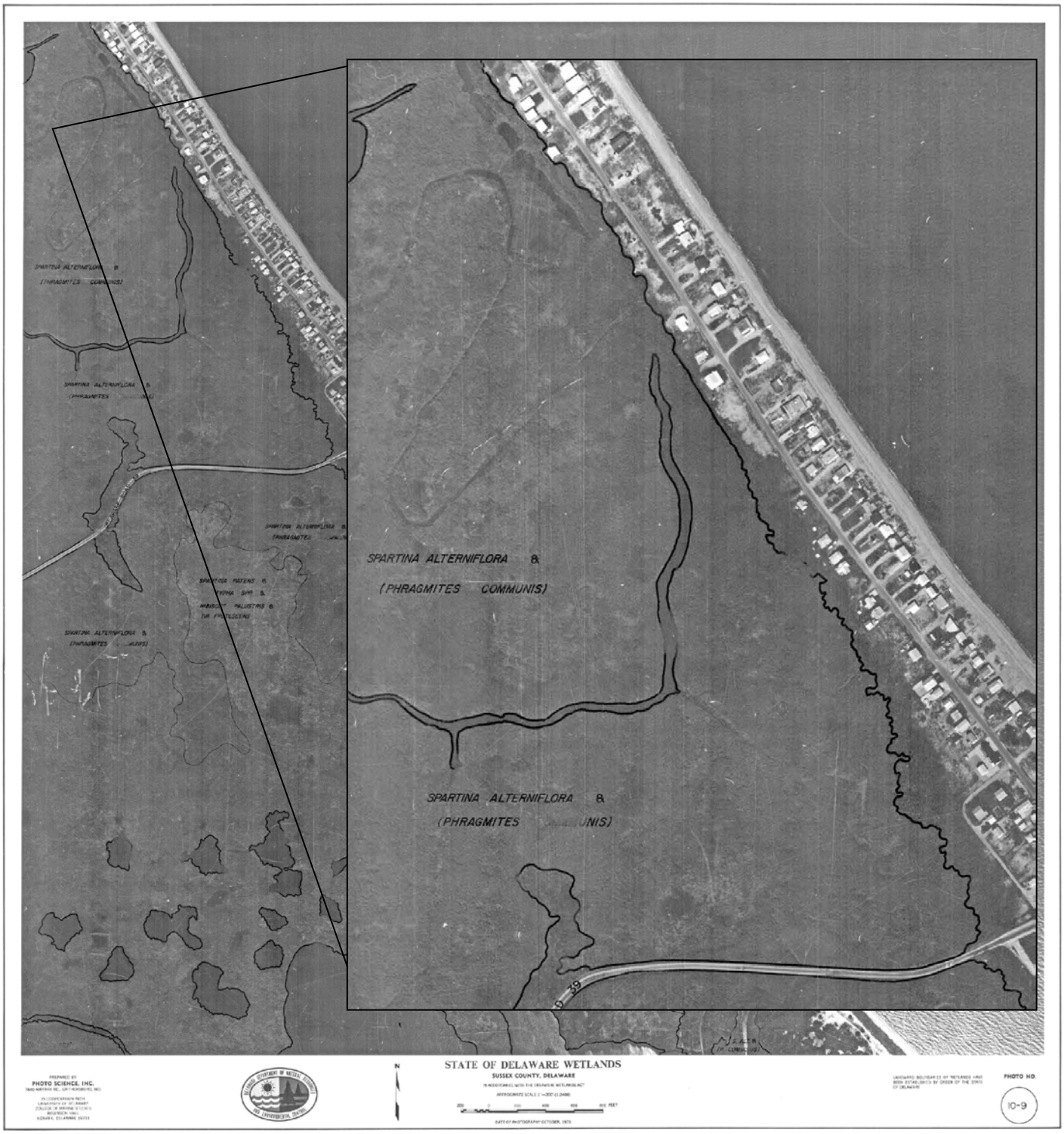
The Unit II impoundment is located behind the project area. The impoundment has been managed as a freshwater marsh since 1988 (USFWS 1986). Vegetation recently present has composed of a mixture of moist soil plant species such as smartweed (*Polygonum spp.*), barnyard grass (*Echinochloa spp.*), and cattails (*Typha spp.*), that are not salt tolerant. Specific vegetation composition can vary annually due to flooding regimes. This manmade system is managed using one water control structure located at the junction of the Slaughter Canal and Fowler Beach Road (Figure 2).

Prior to water control conducted by the Service, Unit II contained a mix of wetland communities (Figure 6 and Figure 7). A survey of Delaware wetlands conducted before the refuge was established reported a mix of salt-, brackish- and freshwater-tolerant vegetation and a wide variety of salinity readings (0.1 – 18.6 ppt) in the vicinity of the present Unit II (Chamberlain 1951). The presence of some brackish or freshwater vegetation in the salt marsh was attributed to a higher barrier along the coast than in locations to the north and south. Wetland maps developed by DNREC, in cooperation with the University of Delaware in the 1970s, delineated extensive salt marsh (*Spartina* sp.) vegetation communities, as well as some freshwater or brackish communities in the Unit II area (DNREC 1971 maps, on file). The maps indicate that much of the former salt marsh community had been invaded by *Phragmites*, likely due to previous alterations of the natural drainage, hydrology, and soils. The 1986 EA, although describing the area as a "former high quality freshwater marsh," also describes existing salt marsh vegetation within the narrative and on the included map. In addition, that EA describes that grid-ditching was conducted on a portion of the unit during the 1930s and 1940s, and indicates that high quality marsh existed in the 1950s.

It is clear from all accounts that the area historically contained a mix of vegetation, including well-established salt marsh communities, although the exact composition and distribution of species may have fluctuated over the years in response to both natural and human-induced changing conditions. The salt marsh present prior to the impoundment installation may have been degraded, intermingled with pockets of

Figure 6. DNREC wetland map depicting vegetation communities present in the Fowler Beach area in the 1970s (photography date = 1973), with inset of project area. The complete collection of full-size maps is on file at the refuge office and at the DNREC Wetlands Office.

Figure 7. DNREC wetland map depicting vegetation communities present in the Primehook Beach area in the 1970s (photography date = 1973), with inset of project area. The complete collection of full-size maps is on file at the refuge office and at the DNREC Wetlands Office.



freshwater vegetation as rain water collected in excavated and natural pools, and subjected to ditching, draining, and other alterations. Salinity is one of the key ecological factors influencing the type of vegetation that will be sustained in wetlands behind barrier beach island shorelines. Salinity variation is biologically very significant. Freshwater is defined as the dissolved salt content of a water column ranging from zero to 0.5 parts per thousand (ppt). Brackish environmental conditions are defined as greater than 0.5 to 29 ppt, and saline conditions range from 30 to 50 ppt. Brackish salinities can further be reduced to three classes: oligohaline, mesohaline, and polyhaline, and saline conditions can be mixoeuhaline, metahaline or hyperhaline.

Desirable moist soil vegetation species that have been targeted for management in refuge freshwater impoundments do best when growing in oligohaline environmental conditions (0.5 to 5.0 ppt) averaging from 1 to 2 ppt. Target moist-soil wetland plants can survive in mesohaline (greater than 5.0 to 18 ppt) conditions but yield smaller annual seed production per acre of wetland habitat compared to plants growing under oligohaline conditions.

From 1991 to 2008, salinity ranges recorded at the water control structure between Units I and II ranged from 0 to 12 ppt with seasonal averages of about 5 to 8 ppt. However, in the past two years these ranges and averages have been steadily increasing. From 2008 to 2010, the formerly freshwater Unit II system has had increasing saltwater intrusion. The 2008 Mother's Day Nor'easter and overwash in Unit I, and subsequent storms, have continually added to the saltwater in Unit II. Salinity ranges in 2009 ranged from 5 to 30 ppt with averages creeping up to 15 ppt. During the first four months of 2010, average salinities reached 20 ppt. In 2008 and 2009, moist-soil vegetation in the northern portion of Unit II was replaced by halophytic vegetation. Species such as glasswort (*Salicornia spp.*), saltmeadow cordgrass (*Spartina patens*), and smooth cordgrass (*Spartina alterniflora*) have recolonized about 20 percent of the area in the northern, more saline portions of the Unit II impoundment, replacing smartweed, barnyard grass, and cattails. A large portion of Unit II is currently either mudflat or open water, and the remainder of the unit is in a state of fluctuation in response to changing salinity levels. Only a small portion of the unit, primarily in the southern half, could still be considered freshwater marsh.

During the spring and summer of 2010, an outbreak of an algal species (Genus *Cladophora*) occurred in the unit, a form of algae that is common in both freshwater and marine systems. Service staff worked with State partners to determine the source of this issue. Although it is not clear exactly why the bloom occurred, it is believed to have been a combination of several factors, including warm weather conditions, excess nutrient levels from dying freshwater vegetation, run-off from high waters flushing nutrients from adjacent farmlands and septic systems, and the vulnerability of a stressed system in transition. Negative impacts of the bloom were aesthetic, not ecological, and while unlikely, could reoccur if freshwater vegetation is killed off from saltwater influxes and salt marsh vegetation is not sufficiently established.

2. Environmental Consequences

a. Alternative 1 (No Action)

If Alternative 1 were implemented, tidal flows established from inlets formed in fall 2009 would continue to introduce new sediments to Unit II that could aid in the restoration of the unit to salt marsh. The higher saline conditions would result in greater halophytic vegetation re-colonizing back-barrier wetlands and washover habitats. Freshwater plant species would continue to decline and may be replaced by salt marsh vegetation species or open water. Without a concerted effort to raise marsh levels, some additional portions of the unit may convert to open water due to subsidence, peat collapse, and low accretion rates, resulting in open water where there had previously been vegetation.

b. Alternative 2 (Proposed Action)

If Alternative 2 were implemented, daily tidal flow would be terminated, trapping higher saline waters behind the stabilized dunes. During growing seasons, these saline waters would increase in salinity due to evaporation and also increase soil salinities. Overwash salinity data taken in 2008, 2009, and 2010 from Units I and II show that this phenomenon occurs even when inlets are open, especially during the summer months. These environmental conditions eliminate the growth of annual freshwater moist-soil vegetation behind stabilized dunes. That area will most likely be colonized by halophytes or salt marsh vegetation if growing conditions allow. Scraping during construction may disturb any newly established American beach grass or overwash dune grassland herbaceous communities; however, to date little vegetation has colonized the site. Planting dune grass after reconstruction may also help reduce impacts because grass roots hold bulldozed sand in place, and may allow ghost crabs (*Ocypode quadrata*) to burrow more effectively (Peterson et al. 2000). In at least portions of Unit II, freshwater vegetation may return as salinity levels decline following restoration of water management capability.

c. Alternative 3

Consequences of Alternative 3 are very similar to those for the Proposed Action, except that more sediment and substrates would be available for salt-tolerant vegetation to colonize Unit II, as washover habitats would not be scraped to stabilize the dune.

C. Impacts on Migratory Birds and Other Wildlife

1. Affected Environment

The refuge project area contains horseshoe crab (*Limulus polyphemus*) spawning habitats, beach nesting habitats for shorebirds, an osprey nesting platform, spring and

fall migration habitats for shorebirds and other migratory birds, intertidal and beach habitats that provide microhabitats for a diversity of infauna (organisms that burrow and reside in marine and sandy sediments) and small fishes.

Barrier island sandy beach and associated coastal habitats are priority conservation habitat types within the Delaware Bay and Mid-Atlantic Region. The undeveloped shorelines and associated salt marsh habitats support the greatest diversity of species of conservation concern. Beach overwashes provide habitats that can sustain many State and federally listed bird species such as piping plover (*Charadrius melodus*), American oystercatcher (*Haematopus palliatus*), least tern (*Sternula antillarum*), common tern (*Sterna hirundo*), and black skimmer (*Rynchops niger*).

Delaware Bay sandy beach and coastal wetland communities also support a noteworthy shorebird migration that has worldwide ecological significance. Despite the heavy loss of these habitats to development, Delaware Bay coastal habitats remain one of the region's and Western Hemisphere's most important migratory stopovers for hundreds of bird species, especially shorebirds. Undeveloped beach and overwash patches are considered important habitats for these birds, regardless of patch size (USFWS 2003).

Shoreline and sandy beach habitats are shaped by storm surges and other physical driving forces like tides. Storm events and daily high tides deposit wrack composed of algae, vascular plant fragments, assorted mollusks, whelk casings, remnants of clams, crabs, other macroinvertebrates, and small fish. Coupled with spawning sites for horseshoe crabs that supply clusters of highly nutritious eggs in the sand, wrack lines provide rich and plentiful natural food resources for migrating and nesting shorebirds in spring and summer. Shorebird nesting seasons range from March 1 to September 1. Peak spring shorebird migrations range from April 15 to June 1, and peak fall shorebird migrations occur from July 1 to September 1. As many as 8,000 shorebirds have been documented using the overwash in Unit I during the spring migration.

Habitats created by overwash fans and spits at the edges of inlets are ideal and highly productive habitats for many species of shorebirds and other migratory birds due to the proximity to both bayside and interior feeding areas. For example, species of concern such as the piping plover and red knot (*Calidris canutus*), utilize these barrier beach and overwash habitats. Due to the amount of manipulation of barrier islands along the Atlantic Coast flyway, these habitats are rare and often degraded or compromised.

Adult horseshoe crabs gather on sandy beach environments in large numbers in spring to dig nests and lay and fertilize eggs. The start of their inshore movement from deep bay and coastal waters is triggered by lengthening daylight hours. Spawning on the Delaware Bay begins during the latter part of May and peaks with the high tide cycles during full and new moons through June. Spawning adults prefer sandy beach habitats in bays and other areas protected from wave energy. Sandy beach habitat must also include porous, well-oxygenated sediments to provide a

suitable environment for egg survival and development. If optimal spawning areas become limited, spawning may occur along peat banks if sand is present or along the mouths of sandy inlets or salt marsh creeks (ERDG 2003).

Numerous waterfowl species utilize the managed freshwater impoundment behind the project area within Unit II. The moist soil vegetation provided by freshwater management provides an abundant food supply, concentrating waterfowl during migration and winter. Peak waterfowl populations range from 21,243 in 1987 to a high of 224,693 in 1999. In 2008, the peak waterfowl population at the refuge was 90,875 birds.

The Unit II freshwater impoundment has been utilized by a variety of reptiles and amphibians. Among the dozen or so species of frogs and toads found on the refuge are several species of state conservation concern, such as the carpenter frog (*Rana virgatipes*) and Cope's gray treefrog (*Hyla chrysoscelis*).

2. Environmental Consequences

a. Alternative 1 (No Action)

If Alternative 1 were implemented, there would be no impact to migratory birds and other wildlife that use the project area as breeding or migration stopover habitat, such as piping plovers, American oystercatchers, black skimmers, numerous species of terns and other shorebirds, diamondback terrapins (*Malaclemys terrapin*), and horseshoe crabs. As Unit II reverts from a freshwater impoundment to a salt marsh, the abundance and/or composition of waterfowl species using Unit II will likely shift. For example, American black duck (*Anas rubripes*) use may increase, while more freshwater-associated species like Northern pintail (*Anas acuta*) may decrease. Overall, the area will still provide valuable waterfowl habitat. Raptors such as osprey (*Pandion haliaetus*) and Northern harriers (*Circus cyaneus*) would likely still utilize the area as they always have. However, if open water habitat is established instead of salt marsh, declines in waterfowl, shorebirds and songbirds would be anticipated. Although open water provides some value for resting and foraging, its wildlife value on the refuge is much less than established vegetated marshes.

Remaining unmanipulated overwash fans and inlets will provide wildlife habitat, which may increase and contribute to increased breeding, feeding, and resting habitats for those species of migratory shorebirds which cluster there. For example, during spring 2010 DNREC biologists noted that red knots, a candidate for federal listing, utilized the overwash area.

Reptile and amphibian species that utilized the freshwater impoundment would be permanently displaced. Although individuals that previously used the impounded wetlands would need to seek alternate suitable habitat, no negative impacts to the populations are expected. Diamondback terrapins, which are estuarine specialists and are among the State's species of greatest conservation concern, would benefit

from an increase in salt marshes behind the coastal dunes (Palmer and Cordes 1988).

b. Alternative 2 (Proposed Action)

If the Proposed Action were implemented, construction activities would not interfere with peak spring and fall shorebird migrations or peak horseshoe crab spawning activities. The refuge manager will coordinate with State and federal biologists who routinely monitor beach nesting birds to guide the work schedule of the project. Piping plovers have not nested in the project area in the past, but have been observed in the area. Weekly beach bird nesting surveys conducted by the State and/or the Service during breeding season would serve to inform all parties so that Proposed Action activities will not be initiated if there are active nesting attempts by either State or federally listed bird species. However, the work is not slated to occur during the breeding season. Once the project is complete, no negative impacts are anticipated for shorebirds, which would likely utilize the project area in the same manner they did before the breaches occurred.

Heavy equipment use, sand pushing, and dune rebuilding activities would occur after August 15, once established beach bird nests have fledged, to minimize negative impacts to spawning horseshoe crabs and beach nesting birds. Conducting the work after October 1 will also avoid peak fall shorebird migration periods. During construction, portions of the shoreline frequently traveled by heavy equipment will likely not be appealing to birds. They will likely find suitable undisturbed portions of the beach to forage and rest. No significant differences are anticipated in use of Unit II by waterfowl once the project is complete. Return of moist soil vegetation in at least portions of the unit would enable waterfowl to utilize those areas as they have during years of impoundment management. Relocation of the sediments from overwash fans will reduce the quality of these areas as wildlife habitat for the migratory bird species that tend to concentrate on these habitats. However, beachfront habitat and sand not relocated as part of the project would remain available, as it was prior to the formation of the breaches.

Reptiles and amphibians that utilized the area as a freshwater marsh would have the appropriate conditions to recolonize some areas. It is likely that some portions of the unit will remain brackish or slightly saline and thus not be suitable for the herpetofauna that have used the area while it has been managed as freshwater impoundment habitat.

c. Alternative 3

The same environmental consequences and mitigation measures would be generally applicable for Alternative 3 as are described for Alternative 2 above.

D. Impacts on Invertebrates

1. Affected Environment

The intertidal areas of beaches and inlets provide habitats for a great diversity and abundance of invertebrates. The environment between the grains of sand harbor interstitial organisms (e.g., bacteria, protozoans, microalgae, and meiofauna [small benthic invertebrates]) that form a distinct food web that supports zooplankton and macroinvertebrates (invertebrates which are retained on a 0.5 mm sieve).

Benthic macroinvertebrates in these habitats can reach high abundance (ca. 100,000 individuals per square meter). Surf zones and tidal inlets are important nursery and foraging areas for fishes and waterbirds because of high densities of invertebrates (Defeo et al. 2009; McLachlan and Brown 2006). The porous sandy substrate of beach ecosystems also filters water, houses and feeds invertebrates that mineralize organic matter, and recycles marine nutrients, making sandy beach habitats a crucial element in the nearshore processing of organic matter and nutrients that help to maintain high densities of invertebrates (Defeo et al. 2009).

2. Environmental Consequences

a. Alternative 1 (No Action)

If the No Action Alternative were implemented, no physical damage to invertebrate populations would occur during construction. Overwash fans and tidal inlets are formed when water flows across barrier-beaches during storm surges or spring high tide cycles, which provides rich influxes of invertebrates to the system. Storm-surge channels that cut through foredune ridges not only serve as conduits for the transport of sediment materials, but also move invertebrates from nearshore environments to the beach face and to back-barrier environments. As the overwash fan builds, the movement of daily water flow will be reduced over time, which will reduce the influx of invertebrates to the back-barrier wetlands of Unit II. This will reduce the tidal invertebrate source available to migratory birds and other wildlife; however, invertebrate availability is not expected to be limited in the unit. Tidal invertebrate sources would recharge the area during storm events and extreme high tides that exceed daily tidal flows.

b. Alternative 2 (Proposed Action)

Construction activities associated with Alternative 2 will cause temporary damage to sandy beach and washover habitats by compacting sand and disturbing the physical environment that supports invertebrates (Peterson et al. 2000). The wrack lines in the project area would be buried by sand or trampled by heavy equipment, which would temporarily disturb invertebrate prey. During construction, shorebirds that may benefit from them will forage on undisturbed portions of the beach. Wrack lines would quickly rebuild with daily tidal cycles once construction was complete.

Scraping washover sediments and rebuilding dune lines can also kill invertebrates by deep burial. Negatively affected invertebrates include benthic macroinvertebrates, terrestrial arthropods like beach dune tiger beetles (*Cicindela dorsalis dorsalis*), and other macroinvertebrates (predominantly crustaceans, mollusks, and polychaete worms). It is expected that due to the sheer volume of invertebrates, these populations would recolonize and recover fairly quickly.

Levisen and Van Dolah (1996) studied infaunal recovery after bulldozing occurred on a beach in South Carolina. Within 60 days, species abundance and diversity of the overall faunal complex and abundance of dominant taxa recovered. This study supports earlier findings that documented quick recovery of invertebrate fauna and no long-term changes to species composition from beach scraping (Baca and Lankford 1988; CSA 1991; Lankford and Baca 1987; Lankford et al. 1988). Peterson et al. (2000) documented a 100 percent increase in abundance of coquina clams (Genus *Donax*) following bulldozing activities. Lindquist and Manning (2001) did not detect any negative impacts to the amphiopod *Amphiporeia virginiana* or the polychaete *Scolelepis squanata*. The Lindquist and Manning (2001) study documented negative impacts to some species, most notably mole crabs (*Emerita talpoida*) and ghost crabs. The cause could not be determined. The majority of bulldozing activity for the Proposed Action will take place on the landward side of the dunes, which should reduce impacts to crabs. Negative environmental consequences could be mitigated if heavy equipment, washover scraping activities, and dune line rebuilding occur toward the end of the summer or later.

c. Alternative 3

The same environmental consequences and mitigation measures would be applicable for Alternative 3 as are described for Alternative 2 above.

E. Impacts on Cultural and Historical Resources

1. Affected Environment

Predictive models provide means for archaeologists and land managers to identify land forms that are likely to contain undiscovered archaeological sites and/or artifacts. These models have been used in the past at the refuge with success when surface disruptive management actions have occurred (Tetra Tech 2004).

Prehistoric cultural contexts in Delaware are described in terms of five major chronological periods that correspond to broad adaptive shifts to changing natural and cultural conditions. These cultural periods are the Paleo-Indian (14,000 to 8,500 BP [Before Present]), Archaic (8,500 to 5,000 BP), Woodland I (5,000 to 1,000 BP), Woodland II (1,000 to 500 BP), and Contact Periods (500 to 300 BP) (Custer 1984). Cultural periods are usually identified from chronologically diagnostic artifacts such

as projectile points, ground and chipped stone technologies, and/or pottery styles during these cultural periods (Tetra Tech 2004).

In Delaware, throughout the prehistoric period, highly productive rivers, streams, wetlands, and beach habitats repeatedly attracted Native Americans. These marine environments changed over millennia. Rising sea levels have progressively inundated the coastal zone of the Delaware Bay and stream drainages in the areas of the refuge for thousands of years (Tetra Tech 2004).

These rising sea levels eroded greater numbers of early Holocene Paleo-Indian and Archaic period sites than later Woodland II and Contact period sites. Recognizing the prehistoric settlement patterns on uplands adjacent to marine habitats (Custer and Galasso 1983) and the effects of sea level rise in former land forms, the likelihood of paleogeography and prehistoric sites on the refuge could be predicted (Tetra Tech 2004). This model was instrumental in structuring archaeological monitoring during open marsh water management (OMWM) work conducted on the refuge for mosquito control. The validity of this model has been demonstrated through the identification of eight prehistoric and two historic sites during OMWM work with artifacts recovered and associated records documented on Delaware Cultural Resource Survey Archaeological Site Forms by the Bureau of Archaeology and Historic Preservation. All artifacts retrieved from these sites are kept at Delaware State Museums in Dover, Delaware.

The project areas may be located on or near moderate-to-high probability zones of prehistoric site sensitivity according to predictive models (Tetra Tech 2004). The shoreline along the refuge, particularly in the vicinity of Unit II, has migrated about 150 to 200 feet in the last 24 years, possibly positioning proposed work on or near potential archaeological zones. However, no known sites exist in the project area and the proposed work will not extend below modern overwash sand. As a part of the regulatory process, concurrence was sought with the State Division of Historical and Cultural Affairs that no historic properties will be negatively impacted by project work.

2. Environmental Consequences

a. Alternative 1 (No Action)

No threats to cultural and historic resources would occur under the No Action Alternative. However, eventual erosion of marshes would likely occur from natural causes, thereby threatening any archaeological resources within them.

b. Alternative 2 (Proposed Action)

The Service's Regional Historic Preservation Officer received concurrence from the Delaware Division of Historical and Cultural Affairs that no historic properties will be affected under the Proposed Action because no historic

structures exist within the proposed work area or its viewshed and all work will be entirely within the horizontal and vertical limits of modern overwashed sands.

While it is possible that archaeological resources exist in marsh deposits beneath the sand, the construction project will require that a minimum of two feet of sand remain in place to provide stability for heavy equipment. That sand has been deposited since fall 2009 so work would not disturb strata deposited prior to that time.

c. Alternative 3

It is expected that no impacts to cultural or historical artifacts would occur if Alternative 3 was implemented.

F. Impacts on Social and Economic Resources

1. Affected Environment

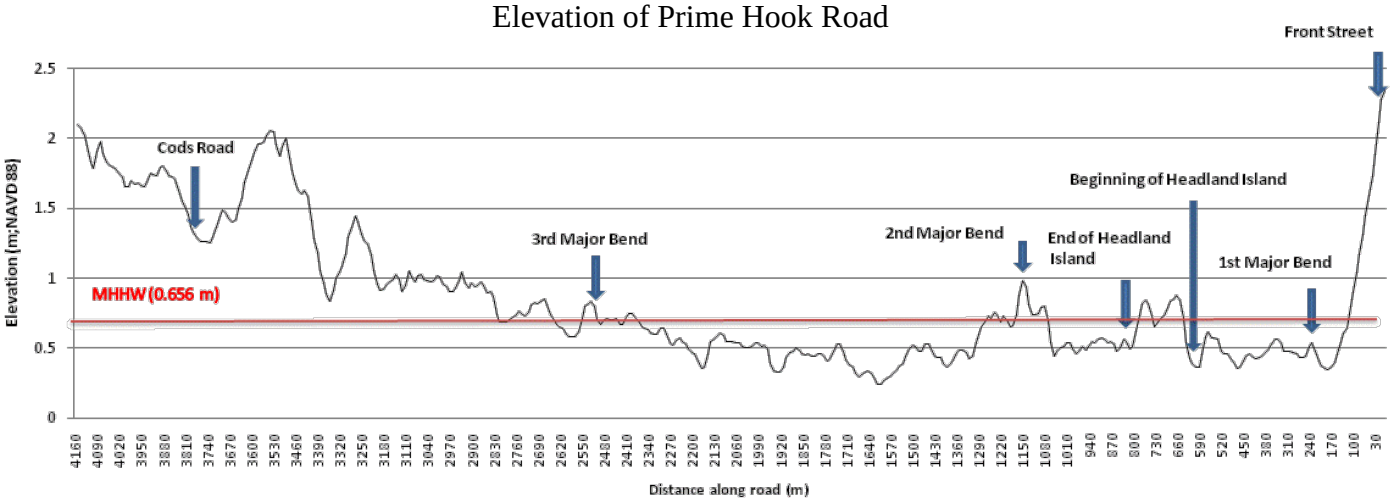
The refuge project site is intertwined with three adjacent landowners, who are all cooperators with the proposed dune line work. No structures are located on the project site. Portions of the beach in the project area are used for recreation, such as fishing, walking, and wildlife observation and photography.

The closest community to the project site is Primehook Beach, which is located approximately one mile south of the project area. As of 2004, there were 206 homes or landowners in the community, including 43 full-time residents and 163 seasonal residents. The only road access to the community is on Prime Hook Road, which is owned by the State of Delaware. Road elevations are extremely low in several locations, below MHHW, which makes transit unsafe and/or nearly impossible during very high tides (Figure 8).

The Prime Hook Beach Organization and several community members have contacted refuge staff repeatedly about concerns that the inlet created in fall 2009 is negatively impacting access and egress to and from their community, and that it has exacerbated flooding in the area. However, the complexities involved in the coastal ecosystem and the trend towards more and higher intensity storms with associated extreme high tides, as discussed earlier in this document, play a significant role in the increased flooding. No single factor can be attributed to the increased flooding in the area.

The Proposed Action has the secondary benefit of alleviating current concerns, while causing minimal environmental impacts, to allow the Service to proceed with data collection and analysis that is vital to the EIS associated with the CCP. The CCP, and subsequent step-down planning, will lay the groundwork and set clear strategies that will address the multitude of factors affecting the refuge and the area, and will guide long-term management of habitat on the refuge.

Figure 8. Elevations of Prime Hook Road in relation to MHHW, along the segment depicted in red on the aerial photograph.



2. Environmental Consequences

a. Alternative 1 (No Action)

If No Action were taken at this time, the local community would continue to be concerned about access and egress to and from their properties. Unfortunately, this issue has caused a significant amount of animosity between some community members and the Service. The lack of action on the part of the Service would not alleviate that situation.

b. Alternative 2 (Proposed Action)

If Alternative 2 were implemented, the local community would benefit from the temporary mitigation of concerns about flooding and shoreline erosion, to the extent that the inlets actually are exacerbating localized flooding. In the meantime, the community members would be afforded the opportunity and the time to review future refuge management plans in more detail through the public comment period of the CCP process and subsequent step-down plans.

c. Alternative 3

If Alternative 3 were implemented, the community would benefit as in Alternative 2. This alternative, however, costs significantly more than the Proposed Action.

G. Cumulative Impacts of the Proposed Action on Sandy Beach Habitats and Reasonably Foreseeable Future Management Actions on the Refuge

The work of local and regional geologists and other scientists continues to inform our understanding of the importance of geology and site-specific geomorphological features with respect to artificially stabilized dunes and their relationship to natural shoreline erosion, accretion cycles, and sediment budgets of barrier island and back-barrier wetlands. Furthermore, by researching the geologic framework of the refuge, we understand that erosion of refuge sandy beach habitats and private beach areas has been exacerbated locally by historic and recent human activities that create "legacy effects" on sediment budgets and the saline environment of refuge coastal habitats. Most of these human effects can have long-term and cumulative sediment supply and salinity consequences. Some of these localized human activities could include:

- Hard armoring of shorelines with cyclic beach nourishment in Slaughter Beach and Broadkill Beach communities,
- Stabilization of Roosevelt Inlet and the construction of inner and outer breakwater seawalls in Lewes, which have changed the direction and intensity of littoral drift and sediment supply along Delaware Bay shorelines (Kraft et al. 1976),
- Significant localized groundwater withdrawals off-refuge that increase and amplify local subsidence effects and intensify cumulative salinity intrusion

effects to refuge ground and surface waters along the marsh/upland interface, and

- Construction of the cross-marsh roads, such as Prime Hook Road and Fowler Beach Road, along with other diking and drainage alterations, which have affected localized flooding, impoundment, and drainage of floodwaters.

Some of the most significant impacts resulting from these activities include blocked and drawn-off littoral sand transport from refuge and Primehook Beach habitats, increased shoreline breaching potential, and expedited barrier island roll-over (Fletcher et al. 1990; Kraft et al. 1976).

Geologists, climatologists, and other scientists clarify that barrier beach island storm-driven processes are dominated by numerous and frequent inlet formations, the development of extensive overwash depositional fans, and higher rates of shoreline erosion. These are all integral processes of barrier beach island migration or roll-over that will occur more frequently in a changing climate (CCSP 2009).

Overwashes and inlets act as safety valves by adjusting and shifting in size and location in response to each and every set of unique storm conditions that generate the various wind and wave-forcing effects on shorelines. Artificial dune line stabilization disrupts the self-adjusting, safety valve function of inlet formation, the sediment by-pass system between island shorelines and the exchange of sediment from near-shore to back-barrier marshes. It negatively impacts sediment budgets of associated wetlands and suppresses natural sand movements in coastal ecosystems (S. Adamowicz, pers. comm. 2010; R. Burdick, pers. comm. 2010; Pilkey and Neal 2009; Riggs et al. 2009).

Shoreline roll-over or retreat is a cumulative effect of rising sea level and has occurred many times in history (CCSP 2009; Kraft et al. 1976; Riggs et al. 2009). Local examples where shoreline retreat is easily observed include the World War II sentinel tower and the refuge observation tower (built in 2006) at the end of Fowler Beach Road. These structures were originally built well behind the dunes and are now located in the bay or intertidal zone. The spatial and temporal effects of building groins, bulkheads, and hard armoring shorelines along Slaughter and Broadkill beaches, and establishing Lewes breakwaters, may have significantly altered the long-shore transport of sediments and reduced natural sand deposition along refuge and Primehook Beach shorelines that are today considered sediment starved. The environmental consequences of coastal erosion and flooding trigger subsequent adaptive responses by natural beach ecosystems that seek new equilibrium points to adjust to sea level rise and increased storminess. The effect of sea level rise is also compounded on gently sloping Atlantic coastal plain shorelines. A one-meter increase in sea level may not seem ominous, but trigonometry indicates that on gently sloping coasts, a one-meter rise could result in landward migration of the shoreline from 200 to 300 meters or more (Coch 2009).

Human activities that repeatedly keep shorelines in place in attempts to minimize impacts of coastal flooding and reduce erosion can and will generate long-term negative environmental consequences for sandy beach and back-barrier marshes along barrier island shorelines that are managed primarily for wildlife and conservation purposes

(Defeo et al. 2009; Pilkey and Young 2009; Riggs et al. 2009). Rebuilding dunes after each storm may be desired to protect private homes and other private property; however, these repeated activities interfere with shoreline recession, barrier beach island evolution and migration, and conditions that facilitate the accretion of back-barrier salt marsh habitats.

A scenario of continual rebuilding of artificial dunes could have long-term and cumulative negative impacts and consequences. The system at Prime Hook NWR and the adjacent community is complex, and much is still not known regarding the effects of the interaction of the multiple factors described in this document. Geologists recommend that artificial dunes not be rebuilt after storm damage to allow tidal inlet and overwash formation that reduces the vulnerability of back-barrier marshes to sea level rise by increasing vertical sediment accretion (Pilkey and Neal 2009; Riggs et al. 2009; Stevenson and Kearney 2009).

Cumulative impacts of human activities that repetitively stabilize dune lines on sandy beach habitats also have the negative consequences of significantly narrowing barrier island shoreline strands. This can ultimately lead to the collapse and disappearance of these ribbons of sand, and significantly increase the vulnerability of back-barrier marshes to sea level rise (Coch 2009; Levine et al. 2009; Pilkey and Young 2009; Reed et al. 2008; Riggs et al. 2009).

Given the information cited above, the Proposed Action is a short-term solution that would allow the management action to occur as needed until decisions regarding future management of all refuge impoundments are made through the CCP and step-down planning processes. This short-term decision does not prevent the Service from implementing a different long-term solution if one emerges from the NEPA/CCP process. All plans will be available for public review and comment.

VI. CONSULTATION AND COORDINATION WITH OTHERS

A. Consultation and Coordination with Other Agencies and Service Programs

Section 7 of the Endangered Species Act and intra-Service coordination and consultation with the Service's Chesapeake Bay Field Office (CBFO) was conducted for Delmarva fox squirrel (*Sciurus niger cinereus*) and piping plover. The CBFO concurred that the Proposed Action is not likely to adversely affect either species.

Activities associated with wetlands (e.g., dune construction) will require a Section 404 permit from the U.S. Army Corps of Engineers (Corps). In addition, the DNREC's Wetland section may require a permit for water quality certification. Permits will be obtained before initiating any project. Section 404 of the Clean Water Act regulates discharge of dredged and fill material to waters of the United States, including wetlands under federal jurisdiction. Section 10 of the Rivers and Harbors Act regulates activities along navigable rivers and waterways. Both are simultaneously administered by the Corps.

Section 401 of the Clean Water Act requires states to certify that activities authorized by the federal government pursuant to Section 404 of the Clean Water Act will not violate the State Water Quality Standards. A project specific application for Water Quality Certification is generally required for all projects requiring an Individual Permit from the Corps, as well as for certain projects that qualify for a Corps Nationwide Permit but are located in environmentally sensitive areas.

In addition, permits must be obtained from DNREC's Division of Soil and Water Conservation (Shoreline and Waterway Management Section). These permits pertain to compliance with the "Regulations Governing Beach Protection and the Use of Beaches" (effective December 27, 1983). This permit regulates construction activities within the defined beach area and landward of the DNREC building line.

Coastal Zone Management Federal Consistency is a process that requires federal agencies to follow State coastal management policies when conducting a project or issuing a permit that could affect coastal resources. It also enables increased coordination between government agencies. The program was established by Congress in 1972 by the Coastal Zone Management Act. Every coastal State implements a Federal Consistency program.

Federal Consistency requires that projects conducted directly by a federal agency, projects authorized by a federal permit and some projects implemented with federal funds be consistent with Delaware's Coastal Zone Management policies. Projects are reviewed by Delaware Coastal Management Program staff in close coordination with other agencies. If projects are consistent with the policies, Federal Consistency "concurrence" is issued.

The Service's Regional Historic Preservation Officer has reviewed this assessment. As a part of the regulatory process, we have received concurrence from the State Division of Historical and Cultural Affairs that no cultural artifacts will be negatively impacted by project work.

B. Public Comments and Responses

The Service published a "Draft Dune Restoration Environmental Assessment at Prime Hook National Wildlife Refuge" on July 27, 2010, with a 30-day-long comment period ending on August 26, 2010. The Draft EA was posted on the refuge Web site with an announcement of availability. On August 7, 2010, refuge personnel held a public open house at the Milton Fire Hall. Over 110 people attended. The Service prepared an EA in compliance with the NEPA to ensure that we are acting in accordance to the letter and spirit of NEPA to foster excellent action, make decisions based on the environmental consequences, and take actions to protect, restore, and enhance the environment (40 CFR 1500-1508).

Written comments were received via mail and electronic mail. A total of 46 comments were received during the 30-day-long open period from the public and various organizations. Three respondents supported Alternative 1, which is the option to take no action. Thirteen respondents supported the Preferred Alternative (Alternative 2), which

is to scrape sand from washover areas in Unit II on Prime Hook NWR to build up approximately 950 feet of dune line on refuge lands and 2,000 feet on private lands south of Fowler Beach, and fill recently created inlets, which are partly on refuge lands and partly on private property. Four respondents supported Alternative 3, which is to conduct dune line repairs and fill existing inlets without scraping sand from refuge lands. All materials needed to complete work on refuge lands would be hauled from off-site sources. Additionally, no materials existing on refuge lands would be scraped to reconstruct dunes and fill inlets on private lands. Sixteen respondents indicated support for Alternative 2, but expressed a preference for Alternative 3, or some combination of the two alternatives. The remaining respondents provided various specific comments regarding the project, without expressing support for any particular alternative.

A synopsis of comments received is presented below with the Service's response. The complete text of all letters and email messages is on file and available at the Prime Hook NWR office. Comments were considered in the preparation of the Final EA.

Summary of written comments

Comment	**Number**
Support for Alternative 1 (No Action – No dune lines would be repaired)	3
Support for Alternative 2 (Preferred Alternative - Short-term soft dune line reconstruction using sand scraped on-site)	13
Support for Alternative 3 (Dune line reconstruction using material from off-site sources)	4
Supports Alternative 2, but would prefer Alternative 3 or some combination of both Alternatives 2 and 3	16

1. Comments Supporting Alternative 1 (No Action)

   Comment: There is not enough available sand to establish a dune line, and breaching or flanking will reoccur probably within a couple of years returning conditions to equilibrium.
   Response: According to DNREC personnel, there is enough sand to construct a dune line. Breaching and/or flanking are common on barrier island systems. Should DNREC determine that insufficient sand is available, they will be authorized to haul in sand from off-site. We cannot predict whether the system will enter a state of equilibrium.

   Comment: The Proposed Action will not accomplish the stated purpose – "to minimize impacts of coastal flooding".
   Response: We believe that the reconstruction of a short-term dune line will reduce impacts of coastal flooding to the immediate area for the short term, while allowing refuge management time to collect additional data regarding the state of the impoundment system. The EA has been updated to make the primary purpose clear.

It has also been amended to state that a reduction in coastal flooding impacts is anticipated but cannot be certain as we do not fully understand the entire hydrologic system. The comprehensive monitoring program will enable the refuge to further define management needs in response to the changing environment, to evaluate management approaches through the CCP process and beyond, and revise or adapt restoration actions in light of the system's response.

Comment: The Proposed Action will not result in any economic benefit and at worst, it can create complacency and place residents at greater risk believing that flooding risks have been reduced when in fact are unchanged.
Response: We hope that the information in this EA, along with other publicly available information, increases the knowledge residents have about the risks of flooding and storms to development in low-lying coastal areas and on barrier beaches.

Comment: Saltwater intrusion has created wonderful habitat for shorebirds.
Response: Comment noted, thank you.

Comment: To carry out the proposal to scrape sand from the refuge for use on private property, the Service must first complete a lawful compatibility process.
Response: We have prepared a compatibility determination for two actions. These are: (1) The access by the State of Delaware across refuge lands to conduct work on the refuge and to conduct work on private lands, and (2) the reconfiguration of the dune/berm by moving some sediments, which have washed off private lands onto the refuge, back onto private lands.

The reconfiguration of sand on refuge lands is a refuge management function and does not require a compatibility determination. While the reconfiguration of sand off of the refuge is being done with the primary purpose of holding the status quo until we can gather additional information and finalize our CCP/EIS and long-term management plan without losing additional marsh substrate in the interim, we recognize that activities to protect refuge lands are generally not conducted on private lands. The compatibility policy (603 FW 2) states that: "We do not require a compatibility determination for refuge management activities as defined by the term 'refuge management activity' except for 'refuge management economic activities.' Examples of refuge management activities that do not require a compatibility determination include: Prescribed burning; water level management; invasive species control; routine scientific monitoring, studies, surveys, and censuses; historic preservation activities; law enforcement activities; and maintenance of existing refuge facilities, structures, and improvements. In addition, we do not require compatibility determinations for State wildlife management activities on a national wildlife refuge pursuant to a cooperative agreement between the State and the Fish and Wildlife Service where the refuge manager has made a written determination that such activities support fulfilling the refuge purposes or the System mission." We consider our Proposed Action a refuge management activity and not subject to compatibility.

This definition of "use" is further bolstered by the fact that the statute specifically exempts from the compatibility requirement actions taken by "persons authorized to

manage" the refuge area. By re-establishing the dune/berm, the refuge is allowing for the continued management of the freshwater system to the benefit of migratory birds. In 1988, the Service entered into a Memorandum of Agreement (MOA) with the State of Delaware's DNREC Division of Fish and Wildlife to enhance waterfowl habitat in Unit II. The purpose of the agreement was to maintain the facility (water control structure) for the estimated life of the structure, which was 20 years. It was amended to include an additional 10 years for a total of 30 years. While we consider the Proposed Action to be consistent with both 603 FW 2 and the MOA with DNREC, since neither of these explicitly address the checkerboard nature of property ownerships and the habitats to be reconfigured here, we have determined to also prepare a compatibility determination for the transfer of any sediments that will be necessary to be moved onto private land in order to benefit the refuge.

Comment: The Proposed Action would result in the taking of a number of migratory bird species in violation of the Migratory Bird Treaty Act (MBTA).
Response: Migratory bird species composition will shift and individual birds will move in and out of the project area as conditions change. "Take" is legally defined as "to pursue, hunt, shoot, wound, kill, trap, capture, or collect, or attempt to pursue, hunt, shoot, wound, kill, trap, capture, or collect" migratory birds (724 FW 2; 50 CFR 10.12), and thus is not applicable to the Proposed Action. As noted by the Ninth Circuit Court (952 F.2d 297), neither the MBTA nor its regulations makes any mention of habitat modification, and such rulings have also been made in additional cases since.

Comment: The project put forward by the Service for this refuge is at odds with the Service's Climate Change Strategic Plan.
Response: The Service's Strategic Plan for Climate Change and associated 5-year Action Plan were recently finalized. Adaptation is one the progressive strategies defined in the plan. Resistance adaptation is further defined as seeking to manage fish and wildlife resources to resist the influence of climate change or to forestall undesired effect of change. These actions will be most effective when the magnitude of climate change is small; or when the magnitude is greater, "to save native species and habitats for the short term until other adaptation options are found." The International Panel of Climate Change (IPCC) defines anticipatory adaptation as "adaptation that takes place before the impacts of climate change are observed; also known as proactive adaptation." Historically, climate change adaptation has been reactive. With our proposed monitoring protocol, our understanding of the effects of climate change on the system increases and uncertainty decreases. With increased information we anticipate implementing increasingly more anticipatory adaptation approaches.

Comment: The Proposed Action violates the Coastal Barrier Resources Act (CBRA).
Response: Prime Hook NWR is included in the John H. Chafee Coastal Barrier Resources System (CBRS), specifically with a designation as an "Otherwise Protected Area" (OPA) due to its status as a national wildlife refuge. The only federal funding prohibition within OPAs is federal flood insurance. All of the federal funding to be spent by the refuge will be restricted to use only within the OPA, i.e. on

federal lands. For additional information, see http://www.fws.gov/habitatconservation/coastal_barrier.html.

Privately owned portions of the project area are designated as CBRS units. The CBRA bans all Federal expenditures on units of the CBRS except for a few clearly defined exceptions. Section 5 of CBRA prohibits federal expenditures for inlet stabilization except for "stabilization projects for fish and wildlife habitats" [section 6(a)(6)(A)] and for "nonstructural projects for shoreline stabilization that are designed to mimic, enhance, or restore a natural stabilization system" [section 6(a)(6)(G)] in order to "minimize the damage to fish, wildlife, and other natural resources associated with the coastal barriers of the Atlantic [coast…] by considering the means and measures by which the long-term conservation of these fish, wildlife, and other natural resources may be achieved." We believe that the refuge's cooperation with the State of Delaware to, at its expense, move some of the sediment now on refuge lands into the CBRS unit, is fully consistent with these provisions of CBRA.

Comment: The Service is vague in its explanation regarding how the Proposed Action supports the Refuge System mission and the refuge purpose. The failure to adequately consider the Refuge System mission and the refuge's very specific management purposes is a violation of the Refuge Improvement Act.
Response: The purpose of the refuge is to provide habitat for migratory birds, and the mission of the National Wildlife Refuge System is to conserve, manage, protect, and where appropriate, restore fish, wildlife, and plant resources and their habitats. Many species of migratory birds of conservation interest utilize managed freshwater marshes, just as many utilize salt marsh habitat. Neither habitat is inherently prioritized within the refuge purpose nor the Refuge System mission. The Proposed Action provides time to further study and monitor the system as the most optimal future management and restoration options are developed that will ensure long-term protection of biological resources, in support of the Refuge System mission and refuge purposes. As stated earlier, the Unit II impoundment was developed to enhance waterfowl habitat.

Comment: The Proposed Action would require annual use of bulldozers and scraping of sand every year.
Response: The EA does not commit the refuge to any annual or long-term restoration of dunes on the refuge. This EA only implies repair of dunes in the short term, as needed, and only with the full cooperation and concurrence of DNREC. The CCP process will provide guidance on long-term management of the refuge, and upon its finalization, the CCP will take precedence over this EA.

Comment: Rather than adopting a policy of rebuilding this shoreline as put forward in the draft EA, the refuge should adopt the guidelines of the Delaware Beach Management Policy, which allows for natural movement of the shoreline on undeveloped State-owned lands.
Response: A large portion of the affected area falls on private land and DNREC has expressed a willingness to exercise their right to perform dune repairs on that private

land. The refuge strives to work closely with DNREC on this project on refuge land, as an extension of that work.

2. Comments Rejecting Alternative 1 in Support of Alternatives 2 and/or Alternative 3

Comment: The Department's rejection of Alternative 1 and the choice to restore the dunes is sound and prudent.
Response: Comment noted, thank you.

Comment: Failure to restore the freshwater marsh is in contravention of the Refuge Improvement Act.
Response: The purpose of the refuge is to provide habitat for migratory birds, and the mission of the Refuge System is to conserve, manage, protect, and where appropriate, restore fish, wildlife, and plant resources and their habitats. Many species of migratory birds of conservation interest utilize managed freshwater marshes, just as many utilize salt marsh habitat. Neither habitat is inherently prioritized within the refuge purpose nor the Refuge System mission. Presence of one habitat or the other on the refuge does not, inherently, violate any law or policy.

Comment: Dune work needs to be completed quickly to prevent further degradation of the system's integrity and provide time to analyze new information and to re-assess refuge management options through the CCP and post-CCP planning process.
Response: Full compliance with all laws, such as the National Environmental Policy Act, as well as applicable permitting processes, require that we carefully consider our actions and provide the public an opportunity to examine them as well. We are attempting to implement our Proposed Action without unnecessary delay.

Comment: Multiple comments expressed concern that significant wildlife has been killed or displaced because of the breaches and the flooding, and suggest that Alternative 1 (No Action) would be devastating to the environment and wildlife.
Response: As the area directly near the breaches is altered by the movement of saltwater, impacts to vegetation and wildlife are localized and temporary. Because such breaches are a natural part of a coastal ecosystem, wildlife populations are well-adapted to persist, even if some individuals may be negatively affected. Furthermore, wildlife species that did not previously utilize the area will begin to appear as new natural vegetation communities become established. Such transitions, whether they are reversed through management or permitted to proceed naturally, can lead to shifts in vegetation communities and wildlife.

Comment: Multiple comments recommend the integration of Alternative 2 and Alternative 3 as an effective and efficient solution to the timely sustainability of the refuge.
Response: Both Alternative 2 (Proposed Action) and Alternative 3 address filling in the breaches south of Fowler Beach Road and the reconstruction of the dune line. We have chosen to implement Alternative 2 with components of Alternative 3 because we believe that combining them will allow the State of Delaware the flexibility to bring

in other sources of sand if there is insufficient sand that can feasibly be moved from federal lands and remain within the constraints of this project and State law.

Comment: Manage the water control structures to allow the restoration of a freshwater marsh to support migratory birds and wildlife-dependent recreation.
Response: Both Alternatives 2 (Proposed Action) and Alternative 3 propose to re-establish the dune/berm but in a more landward location which still will slow or halt movement of saltwater into Unit II. Subsequently, Unit II would be managed primarily with freshwater, for at least the short term.

Comment: Breaches are causing horseshoe crabs to die and their spawning areas are being destroyed.
Response: Beaches within estuaries, such as in the Delaware Bay are preferred by horseshoe crabs over beaches along oceans because they are low energy environments and are protected from the surf, thus reducing the risks of stranding during spawning events. Horseshoe crabs also prefer to spawn in close proximity to an inlet. Alternative 1 (No Action) will likely benefit horseshoe crabs both by increasing spawning habitat and providing nursery grounds for juveniles. Horseshoe crabs are well-adapted to persist in the dynamic coastline ecosystem. Alternatives 2 and 3 will not eliminate the beach habitats which can be used by horseshoe crabs but they will not have access to the entire overwash fan.

Comment: Multiple comments in support of Alternative 3 to preserve the community of Primehook Beach and the health and safety of community residents were made. One commenter questioned the principle of using public funds to protect beaches that are not accessible to the general public.
Response: The purpose of both the Proposed Action and Alternative 3 would be to preserve management capability within Unit II to meet refuge purposes for migratory birds, and to permit time for the collection and analysis of water and marsh monitoring data. The purpose of both alternatives is not explicitly related to beach or community protection. Prime Hook Beach is a private beach, whereas refuge portions of Fowler Beach are open to the public.

Comment: The breaches and overwashes have flooded roads and endangered the health and safety of Prime Hook Beach residents in the event of an emergency. Funds are wasted on road repairs.
Response: Prime Hook Road is maintained by the Delaware Department of Transportation (DelDOT). Maintaining the road to adequately function during storm events is a DelDOT responsibility. The refuge will continue to work with DelDOT to address the situation because the road is located, via an easement, on federal land. While we recognize the repair of the dunes may temporarily reduce the frequency and alleviate the extent of the flooding of Prime Hook Road, it is clearly not the only factor affecting the road flooding issues. Because Prime Hook Road is 18 inches lower than normal spring tides in several places, flooding will continue to occur to some extent, regardless of whether the dunes are repaired or not. It is also unclear how much the road serves to hold in flood waters and prevent draining of the system after large storms.

Comment: DNREC, DelDOT, and the Service need to work together to permanently fix the breaches.
Response: The refuge has consulted with DNREC and DelDOT regarding an appropriate plan to reconstruct the breached dune line, as evaluated in this EA for the short term. We will continue to work with the State of Delaware on a comprehensive coastal management strategy that best addresses the objectives of all three agencies, within the limitations of the resources and capabilities of each.

Comment: Isn't it a direct conflict in the refuge's mission to allow units 2 and 3 to revert to saltwater which is resulting in the loss of birds and other wildlife in need of a freshwater habitat?
Response: The purpose of the refuge is to provide habitat for migratory birds. Both freshwater marsh and salt marsh contribute in a valuable manner to this purpose, although each in different ways. Many species of migratory birds of conservation interest utilize salt marsh habitat, just as many utilize freshwater marsh. Neither habitat is inherently prioritized within the refuge purpose.

Comment: Alternative 1 will further harm the refuge and making living at Slaughter Beach more dangerous.
Response: Prior to the conversion of Unit II from a brackish or salt marsh to a freshwater marsh system, the refuge was not aware of any harmful affects to the refuge resulting from a brackish or saltwater system. The Wildland Urban Interface (WUI) Initiative to protect over 750 homes in the three adjacent beach communities is an informal partnership that was established that will continue to ensure maintenance of fuel reduction treatments. The refuge has long-standing mutual aid agreements with Memorial Volunteer Fire Department (Slaughter Beach) and Milton Fire Department, Inc. Also the refuge is a party to a Cooperative Fire Control Agreement with the Delaware Department of Agriculture, Forestry Unit.

Comment: No flooding in the Prime Hook Beach Community has occurred from spring floods until the breaches at Fowler Beach occurred; the threat from coastal storms and the resulting flooding are made exponentially worse by the breach in the dune at Fowler Beach.
Response: As stated in the EA, barrier beach inlet formation can be inappropriately labeled as the only cause of flooding of private property during storm events. Yet there are many other extenuating causes and effects involved, such as increased storms and storm intensities, heavier precipitation patterns, extreme wind and wave conditions, extensive run-off from uplands, low elevation of roads and private properties with respect to local mean sea level, local geologic features, sediment supply, and human activities. These factors increase the level of complexity of coastal flooding seen at the refuge and adjacent private lands. In 2009, storm events increased in frequency and intensity and were associated with extreme high tides, which were well-documented by the National Oceanic and Atmospheric Administration. These played a significant role regarding flooding.

3. Miscellaneous Comments

Comment: The draft EA does not address the natural resources within impoundments II and III. Refuge management activities were geared towards protecting impoundments II and III as freshwater marshes for two decades.
Response: The refuge is still managing Units II and III as freshwater impoundments, to the extent feasible within the practicalities of current saline levels and until this EA process and receipt of other permits allow us to take action. The Proposed Action would support that continued management, at least in the short term. The management regime implemented over the past two decades will be revisited during the CCP process through an evaluation of refuge management objectives and capabilities.

Comment: There are inconsistencies between the background and history section of the 1988 and the current EA. The refuge was established as a freshwater refuge.
Response: Prime Hook National Wildlife Refuge was established in 1963 to preserve and protect coastal wetlands as habitat for migratory birds. Although Unit II was managed as a freshwater impoundment beginning in 1988, historical maps indicate that the unit contained both freshwater and salt marsh wetland communities prior to that time. In preparation of this EA, refuge staff compiled as much historic wetland data as possible, including a review of the 1986 EA that evaluated establishment of water control in Unit II. Wetland maps developed in the 1970s by DNREC, in cooperation with the University of Delaware, delineated extensive salt marsh vegetation communities, as well as some freshwater or brackish communities, in the Unit II area. Excerpts of the relevant maps and some expanded discussion of previous conditions have been added to the EA, and the entire set of maps is on file at the refuge and in the DNREC Wetlands office. The 1986 EA, although describing the area as a "former high quality freshwater marsh," also describes existing salt marsh vegetation within the narrative, and on the included map. In addition, that EA describes that grid-ditching was conducted on a portion of the unit during the 1930s and 1940s, and indicates that high quality marsh existed in the 1950s. Grid-ditching is a technique used in salt marshes during that era, not in freshwater marshes, which can alter drainage patterns. *Phragmites* became established throughout the tidal area due to alterations of the natural drainage, hydrology, and soils. It is that infestation that largely prompted the Service to develop the freshwater impoundments. It is clear from all accounts that the area contained a mix of vegetation, including well-established salt marsh communities, although the exact composition and distribution of species may have fluctuated over the years in response to changing conditions. The area has long been heavily altered by human activities, and the salt marshes present prior to the impoundments may have been degraded, intermingled with pockets of freshwater vegetation as rain water collected in excavated and natural pools, and subjected to ditching, draining, and other alterations that had taken place.

Comment: The Service has made a commitment to freshwater marshes in Prime Hook NWR and to abandon that commitment would be a complete breach of faith to the people of the surrounding environs and the State of Delaware.

Response: The refuge was established for the purpose of migratory bird conservation without any implicit commitment to a particular habitat type to achieve those purposes. Both freshwater and salt marsh communities existed on the refuge prior to establishment of the impoundments. Furthermore, the 1986 EA, developed to establish the water control structure for Unit II, acknowledged that water sources for the impoundment could include a range of salinities, including water from Delaware Bay. A 1988 Memorandum of Agreement with State of Delaware's DNREC Division of Fish and Wildlife established the Service's intention to manage wetlands within the impoundments for no longer than the life span of the water control facilities, which was estimated to be 20 years. The agreement was amended to include an additional 10 years, for a total of 30 years or for the life of the project.

Comment: The Service has been fixing dunes for years without any problems and now decides to conduct an EA.
Response: It would probably have been prudent for the Service to conduct assessments for previous dune work, but that did not occur. Full compliance with all laws, such as NEPA and permitting processes, requires that we carefully explain our decisions and allow the public the opportunity to examine our Proposed Action. Until recently, the refuge has worked with the State to cooperate or contribute towards the maintenance of beach front dunes south of Fowler Beach Road on both Service and private lands (with private landowner permission). Prior to this last decade, the Service only owned 330 feet of the 1.5 miles of dune line south of Fowler Beach Road. Originally, the need for such maintenance occurred every 10 years or so and was limited to overwashes, not breaches. However, the recent barrage of intense storms occurring in three of the last four years prompted staff to re-assess the situation. The increasingly intense storms have resulted in greater alteration of the dunes and the formation of inlets along with overwashes.

Comment: Flooding of Prime Hook Beach Road is due to inability of water control structures to handle the increase flow of saltwater from Delaware Bay.
Response: As stated earlier in the EA, barrier beach inlet formation can be inappropriately labeled as the only cause of flooding of private property during storm events. Yet there are many other extenuating causes and effects involved, such as increased storms and storm intensities, heavier precipitation patterns, extreme wind and wave conditions, extensive run-off from uplands, subsidence, low elevation of roads and private properties with respect to local mean sea level, local geologic features, sediment supply, and human activities creating dikes, roads, water withdrawals, obstructing sediment transport, etc. These factors increase the level of complexity of coastal flooding seen at the refuge and adjacent private lands. In 2009, storm events increased in frequency and intensity and were associated with extreme high tides that played a significant role regarding flooding. When the EA for establishment of the Unit II water control structure was conducted over 20 years ago, it acknowledged that one source of water for the impoundments might be overwash of the dunes, yet concluded that flooding of the road would not be a significant impact and the project moved forward.

Comment: Exclusive use of Alternative 3 is expensive.

Response: Comment noted, thank you.

Comment: The Refuge has tarried in making a decision.
Response: Comment noted, thank you.

Comment: Refuge staff should have conducted a formal town hall-style meeting.
Response: The refuge staff felt that the open house format would provide more opportunity for an open dialogue in a casual atmosphere, rather than limiting participants to time constraints and only a single turn at the microphone, which is typical of town hall-style meetings.

Comment: Several comments were received regarding long-term management solutions.
Response: A complete analysis of the refuge's long-term plans will be addressed in the CCP. The CCP is currently under development and will outline multiple, large-scale and long-term factors that contribute to habitat management decisions over the next 15 years. The CCP will address impoundment and shoreline management in further detail and will contain long-term strategies to manage wildlife while considering the impacts to the surrounding community. The refuge will analyze new information and re-assess refuge management options through the CCP and post-CCP planning process. The draft CCP will be available for public review and comment later this winter.

Comment: A potential fire hazard is present due to dead trees from saltwater intrusion.
Response: Refuge staff has removed several dead trees on the refuge that we believed had the potential to impact private property, and the refuge will continue to mow a firebreak adjacent to the community to minimize potential fire hazard. The Wildland Urban Interface (WUI) Initiative to protect over 750 homes in the three adjacent beach communities is an informal partnership that was established that will continue to ensure maintenance of fuel reduction treatments. The refuge has long-standing mutual aid agreements with Memorial Volunteer Fire Department (Slaughter Beach) and Milton Fire Department, Inc. Also the refuge is a party to a Cooperative Fire Control Agreement with the Delaware Department of Agriculture, Forestry Unit.

Comment: The plants and birds are gone and the water is covered with algae due to saltwater intrusion.
Response: Migratory bird species composition will shift and individual birds will move in and out of the project area as conditions change. Blooms of *Cladophora* algae can occur in both saltwater and freshwater. Shortly after the algal bloom occurred in Unit II, a team of Service biologists from the Chesapeake Bay Field Office gathered water and algae samples to help determine its cause. Through subsequent analysis by the University of Maryland, the algal bloom was determined to not have been a result of saltwater intrusion into Unit II. Although the exact combination of factors that caused the bloom may never be understood, the overabundance of this naturally occurring species may have been a result of an increase in nutrient concentrations in the waterbody.

Comment: Spoils from the Delaware Bay channel dredging project should be used to restore the dunes.
Response: The beneficial use options for the Delaware Bay Channel Dredging Project spoil material were developed through a NEPA process several years earlier in the planning of the channel deepening project. Those documents stipulate that the material be used in the manner that was proposed, which includes Broadkill Beach and does not include other beaches in the area.

Comment: Saltwater intrusion is impacting agricultural lands adjoining the refuge.
Response: Flooding of some areas of adjacent farmland has been a long-term problem which pre-dates the 2006 overwash in Unit I. Moreover, saltwater intrusion and flooding are common phenomena on many coastal Delaware farms, and throughout coastal areas of the eastern U.S. As stated earlier in the EA, barrier beach inlet formation can be inappropriately labeled as the only cause of flooding of private property during storm events. There are many other extenuating causes and effects involved, such as increased storms and storm intensities, heavier precipitation patterns, extreme wind and wave conditions, extensive run-off from uplands, subsidence, low elevation of roads and private properties with respect to local mean sea level, local geologic features, sediment supply, and human activities creating dikes, roads, water withdrawals, obstructing sediment transport, etc.. These factors increase the level of complexity of coastal flooding seen at the refuge and adjacent private lands.

Comment: Saltwater intrusion is causing drinking water and groundwater contamination.
Response: As sea level rises, so does the groundwater table, thus making it more susceptible to encroachment by saltwater, independent of refuge management.

Comment: Waterways have been contaminated due to flooding.
Response: While the commenter does not specify which waterways they believe have been contaminated due to flooding, we note that no waterways in the vicinity of the breach have been contaminated in any manner that has been directly linked to refuge management. Waterways throughout Delaware experience temporary and fluctuating water quality levels as a result of the interaction of many factors, such as rainfall and run-off over residential and agricultural lands. DNREC maintains a statewide program to monitor water quality.

Comment: Septic systems have been compromised.
Response: Whenever the water table is high or septic systems are threatened by flooding they are at risk. As stated earlier in the EA, barrier beach inlet formation can be inappropriately labeled as the only cause of flooding of private property during storm events. There are many other extenuating causes and effects involved, such as increased storms and storm intensities, heavier precipitation patterns, extreme wind and wave conditions, extensive run-off from uplands, subsidence, low elevation of roads and private properties with respect to local mean sea level, local geologic features, sediment supply, and human activities creating dikes, roads, water

withdrawals, obstructing sediment transport, etc. These factors increase the level of complexity of coastal flooding seen at the refuge and adjacent private lands. In 2009, storm events increased in frequency and intensity and were associated with extreme high tides, well-documented by NOAA, that played a significant role regarding flooding.

Comment: If dunes are to be built up, 1.) do not conduct dune restoration during the migration season and 2.) leave island sandbars intact for bird habitat.
Response: The EA states that work would take place after August 15, and in fact will happen no earlier than November. Thus, construction activities would not interfere with peak spring and fall shorebird migrations. The refuge will coordinate with State and federal biologists who routinely monitor beach nesting birds to guide the work schedule of the project. The EA has been edited to clarify that only a portion of the available sediments on refuge lands will be scraped for dune reconstruction, thereby leaving considerable amounts of sand as island sandbars for bird habitat for foraging and resting.

Comment: Why wasn't any emergency action taken on the current flooding under ESM 10-11?
Response: Although the issues regarding the breaches and related flooding are a serious concern, we do not believe the situation rises to the level of an emergency. Full compliance with all laws, such as NEPA, requires that we carefully explain our decisions and allow the public the opportunity to examine our Proposed Action. Additionally, the EA allows us to cooperate with DNREC on additional repairs to the dune system until the long-term plans for Unit II are finalized through the CCP process and any step-down planning that would result.

Comment: Inaction by the Service amounts to the "taking" of property of the residents of Prime Hook Beach.
Response: The refuge is not responsible for land changes caused by natural events such as major storms, which impact not only the refuge, but the entire Delaware coast. The refuge is also not exclusively responsible for the several other factors that contribute to coastal flooding, such as heavier precipitation patterns, extreme wind and wave conditions, extensive run-off from uplands, subsidence, low elevation of roads and private properties with respect to local mean sea level, local geologic features, sediment supply, and human activities creating dikes, roads, water withdrawals, obstructing sediment transport, etc. These factors increase the level of complexity of coastal flooding seen at the refuge and adjacent private lands. How refuge lands are managed are discretionary decisions, but always subject to specific laws that created the National Wildlife Refuge System and direct how refuges are to be managed. We invite public involvement with the long-term decisions concerning refuge management that will be made via the CCP/EIS process, anticipated later this winter. Furthermore, the refuge does not prevent private landowners from dune restoration on their own land. As long as marsh-side landowners obtain the appropriate State permits and are not filling or harming refuge lands, the refuge does not prevent such landowners from addressing their concerns with flooding of their

own property. Thus, there is no basis for a claim of "a taking" of private property by the Service.

Comment: Refuge needs to rebuild the dune at the north boundary of Prime Hook Beach because of its potential to form a breach.
Response: Comment noted, thank you.

Comment: Alternative 2 provides no financial benefit to a private landowner.
Response: As stated elsewhere in this EA, due to the multiple, confounding factors concerning the hydrology of this area, it is not clear whether or not there will be a reduction in flooding from this project for marsh-side landowners with developed property. If so, presumably this would be of some financial benefit, but it is unclear how much.

The three private landowners who have undeveloped parcels on the barrier island interspersed amongst refuge lands may receive some sediment that the State will move from the overwash areas on refuge land. The Service is unaware that these three landowners have independently conducted any beach manipulation actions other than allowing the State to enter and do this work. Presumably, since these landowners have allowed the inlets to remain, they are managing their lands to allow natural processes to continue while also cooperating with any State or refuge dune/berm restoration actions. It is unclear what financial benefit these efforts may provide to these three landowners, since these lands, given the repeated and increasing propensity to be overwashed by storms, presumably have a relatively low fair market value, and the actions proposed here are anticipated to have short-term effects.

Comment: Please list the public meetings attended by refuge management.
Response: The wording in the EA regarding that stage of project development has been clarified to explain that an Open House was held at the Milton Fire Hall which was attended by over 110 people.

Comment: Please describe why the dune specifications (4.0 feet high) within the draft EA are in conflict with those described in the Delaware State Management Plan for Delaware Bay Beaches.
Response: The referenced State management plan was prepared for developed beach areas, based on preparing those areas for a typical 10-year storm. The engineering recommendations for Prime Hook Beach do not necessarily apply to undeveloped beach outside the area analyzed within the plan. The specifications for the dune work proposed within this EA were developed by considering the limitations of available funding and sand, in combination with identifying a dune/berm size that would provide some protection in the short term. We are continuing to work closely with the technical experts within the DNREC Soil and Water Division on design of any dune work to be conducted on the refuge.

Comment: New mosquito breeding pools have been established.

Response: Mosquitoes breed in standing or quiet water. Biological mosquito control techniques like open marsh eater management (OMWM) takes advantage of this fact. OMWM involves the use of creating shallow ditches to create a network of water flow within marshes to circulate and deliver fish resources that will feed on mosquito larvae. The breaches have significantly increased water flow, tidal range and the density of fish populations accessing the refuge's marshes. Increased water flow throughout the refuge, influenced by strong tidal flows resulting from the three breaches, has virtually eliminated any pockets of standing water. Increased tidal flows have also increased the numbers of mosquito predators in the form of fishes entering the marsh system. Therefore, these two factors have likely served as a source reduction of breeding mosquitoes and have not resulted in any increased mosquito breeding nor established any new mosquito breeding pools.

Comment: The EA did not address the fact that the overwashes occur in areas where water previously emptied into the Delaware Bay, which may be important for future management.
Response: Further review of historical geological maps and documents may be helpful to guide future management through the CCP process and beyond. We do not believe all overwashes occur in former creeks or channels. Soil tests would have to be conducted to ultimately prove or disprove the former existence of creek channels.

Comment: The EA does not address the invertebrates in the wetland soils, which will be destroyed by beach scraping.
Response: As discussed in Section D of the Affected Environment, numerous studies have shown that impacts from the Proposed Action to the invertebrate community within the beach substrate are likely to be temporary. The Proposed Action will involve scraping where there is sufficient sand (about 18-24") to support equipment, and thus will not involve scraping in wetland soils.

Comment: The Service must prepare an Environmental Impact Statement (EIS).
Response: The Service has prepared a Finding of No Significant Impact, which is the decision document for the regional director to determine whether the effects of this project are neither so significant nor major that they would require preparation of an EIS. The Prime Hook NWR CCP, which is anticipated to be released later this winter, will evaluate the various alternatives and impacts of such alternatives, in order to develop a long-term (about 15 year) management plan for coastal habitat and barrier island management as well as the long-term restoration goals for each unit of the refuge. Additional management issues (hunting, upland and agricultural land management, mosquito management, other public uses, etc.) will also be evaluated in the draft CCP/EIS. We invite the public to actively participate in that process.

Comment: The Service has not conducted the required Endangered Species Act Section 7 consultation.
Response: The Service consulted with the Chesapeake Bay Field Office (CBFO) Endangered Species division during preparation of the EA. The Service found that piping plovers and Delmarva fox squirrels were not likely to be adversely affected, and the CBFO has provided concurrence.

Comment: The Service failed to analyze the alternative of elevating Prime Hook and Fowler Beach Roads, which are located on refuge property.
Response: The Delaware Department of Transportation (DelDOT) maintains a 50-foot-wide easement on these roadbeds. These easements transfer the right and responsibility of road management to DelDOT, which includes the right to grade and slope for the purpose of relocating, constructing, widening, improving, and maintaining a State Highway in, on, over, or across said lands. As such, analyses of actions that are the responsibility of DelDOT are outside the scope of this EA. We will continue to work with the State of Delaware on any road improvement evaluations that will alleviate flooding while ensuring that refuge resources are not significantly impacted.

Comment: DNREC concludes that the No Action Alternative would not impact wildlife and migratory birds using the proposed project area for breeding or migration stopover habitat.
Response: Comment noted, thank you.

Comment: It appears that the draft EA inappropriately minimized the costs of its Preferred Alternative.
Response: The Service's cost estimates were based on past work.

Comment: DNREC notes that the beach in the vicinity of the breaches south of Fowler Beach Road is sand starved and does not have enough sand available to re-create dunes at the recommended dimensions noted in the draft EA, and thus recommends that the Service augment available on-site sand with sand from off-site sources.
Response: After DNREC submitted their original comments, their personnel conducted a survey of the area and determined that enough sand exists in the area to rebuild a dune/berm in an alignment that is as far west as possible, given the other design constraints for this project.

Comment: DNREC recommends that the work be completed between October 1 and October 22, to minimize disturbance during peak shorebird migration, and to minimize safety concerns during duck hunting season.
Response: The refuge has other overwash and shorebird habitats available during the shorebird migration. Due to the abundance of habitat, disturbance should be minimized. Unit II is not open to waterfowl hunting so safety concerns are minimized.

Comment: DNREC suggests that it should be acknowledged that red knots, a candidate for federal listing, used the overwash area for foraging and roosting during spring 2010.
Response: The EA has been modified to reflect the use of the project area by the red knot, a candidate species.

Comment: The refuge incorrectly states that the "overwash dune grassland community" is "not extremely rare."
Response: Comment noted, thank you. This has been corrected within the EA.

Comment: An alternative not addressed was to dredge sand from off-shore and pump it onto the beach.
Response: We have added this suggestion to the section describing alternatives considered and not pursued.

Comment: This work is not pursuant to any approved management plan.
Response: In 1988, the Service entered into a Memorandum of Agreement with the State of Delaware's DNREC Division of Fish and Wildlife to enhance waterfowl habitat in Unit II. The agreement was to maintain the facility (water control structure) for the estimated life of the structure, which was 20 years. It was amended to include an additional 10 years for a total of 30 years or as long as the project life. One of the State's conditions for the wetland permits was to restore the dune line. Shoreline management was not addressed in any plan. Prior to this last decade the Service only owned 330 feet of dune line south of Fowler Beach Road and the State conducted all of the dune management activities along the barrier island.

Comment: If the dune is restored, it should be seeded with vegetation.
Response: The EA states that the dune would be revegetated with American beachgrass.

Comment: The dune areas to be scraped are jurisdictional wetlands. The Service will need permits from the U.S. Army Corps of Engineers.
Response: The refuge and State will need a section 404 permit from the Corps of Engineers, DNREC's water quality certification, shoreline (dune) permit, and Coastal Zone Management Federal Consistency review before the project can proceed.

Comment: Impacts to reptiles and amphibians were not considered.
Response: The EA has been modified to include impacts from each of the considered alternatives to reptile and amphibian species.

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Glossary

Accretion: The accumulation of sediments that deposit and increase the size of a land or marsh area. This increase may be lateral or vertical.

Accretion, lateral: The extension of land by natural forces acting over a long period of time, as on a beach by the washing-up of sand from the sea or on a floodplain by the accumulation of sediment deposited by creek or stream.

Accretion, vertical: The vertical accumulation of a sedimentary deposit that increases the thickness of sediment layers.

Armored shoreline: The placement of fixed engineering structures, typically rock or concrete, on or along a shoreline to mitigate the effects of coastal erosion. Such structures include seawalls, bulkheads, and riprap.

Back-barrier: Of or pertaining to area of land between barrier island areas and the mainland.

Back-barrier flats: Low-lying sandy regions on the landward side of sand dunes often covered with salt-tolerant grasses and shrubs.

Back-barrier marshes: Marsh formed on the landward side of a barrier beach island, often containing significant coarse sediment that has washed in from the bay or seaward side.

Barrier island: A long, narrow coastal sandy strip parallel to the shore, the crest of which is above normal high water level, and that commonly has dunes, vegetated zones, and remnant marsh terraces extending landward from the beach. It is usually built up by the actions of waves and currents.

Barrier island roll-over: The landward migration or landward transgression of a barrier island, accomplished primarily over decadal or longer periods of time through the process of storm overwash, periodic inlet formation, and wind-blown transport of sand.

Barrier migration: The movement of an entire barrier island in response to sea level rise, changes in sediment supply, storm surges or waves, or some combination of these factors.

Beach erosion: Carrying away of beach materials, mostly sand by wave action, tidal currents, littoral currents, wind, or storm surges.

Beach nourishment: The addition of sand, often dredged from offshore sources, to an eroding shoreline to enlarge or create a beach area, offering temporary shore protection and recreational opportunities on public beaches. It is the most popular soft engineering technique of coastal defense management schemes.

Breach: A channel through a barrier island typically formed by storm waves, tidal action, or barrier migration. Breaches commonly occur during high storm surge caused by hurricanes or Nor'easters.

Coastal Plain: Any low-lying areas bordering the bay or ocean, extending inland to the nearest elevated land, and sloping very gently towards the water.

Dike: A wall of earthen materials designed to prevent the permanent submergence of lands below sea level, tidal flooding of lands between sea level and spring high water, or storm-surge flooding of the coastal floodplain.

Downdrift: Refers to the location of one section or feature along the coast in relation to another; often used to refer to the direction of net longshore sediment transport between two or more locations (i.e., downstream).

Dune line: Any natural hill, mound, or ridge of sediment landward of a coastal berm deposited by the wind or by storm overwash, capable of movement from place to place and may be either bare of covered with vegetation. A dune line is linear in nature. An artificial dune is sediment deposited by artificial means and serving the purpose of erosion control and storm-damage prevention.

Duration: In wave forecasting, the length of time the wind blows in nearly the same direction over a body of water.

Ebb tide: The period of the tidal cycle between high water and low water; a falling tide.

Erosion: The mechanical removal of sediments by water, ice, or wind. In the context of coastal settings erosion refers to landward retreat of a shoreline indicator such as the water line, or berm crest. The loss occurs when sediments are entrained into the water column and carried landward or seaward.

Fetch: The area of open water where winds blow over with constant speed and direction, generating waves.

Flood tide: Period of time between low water and high water; a rising tide.

Forcing: To hasten the rate of a process or growth; with respect to coastal sensitivity to sea level rise, forcing generally refers to climate change factors that act to alter a particular physical, chemical, or biological system such as changes in climate like CO_2 concentration, temperatures, sea level, or storm characteristics.

Geologic framework: The underlying geological setting, structure, and lithology (rock or sediment type) of a given area. The geologic framework of Prime Hook Refuge's shoreline habitats is characterized as a saline fringe, wave-dominated barrier island setting.

Geosyncline: A very large, troughlike depression in the Earth's surface containing masses of sedimentary and volcanic rocks

Geomophology (geomorphic): The external structure, form, and arrangement of rocks or sediments in relation to the development of the surface of the Earth.

Global sea level rise: The world-wide average rise in mean sea level; may be due to a number of different causes, such as the thermal expansion of sea water and the addition of water to the oceans from the melting glaciers, ice caps, and ice sheets; contrast with *relative sea level rise.*

Groin: An engineering structure oriented perpendicular to the beach, used to accumulate littoral sand by interrupting longshore transport processes; often constructed of concrete, timbers, steel, or rock.

Holocene: A geological epoch which began approximately 12,000 years ago. According to traditional geological thinking, the Holocene continues to the present. The Holocene is part of the Quarternary period. It is identified with the current warm period and is considered interglacial in the current Ice Age.

Infauna: Aquatic animals live within the bottom substratum of a body of water, such as a soft sea bottom, rather than on its surface

Littoral: Area between high and low tide in coastal waters.

Littoral transport: The movement of sediment such as sand and stones near the shore (littoral drift) in the littoral zone by waves and currents; includes movements parallel (longshore transport) and perpendicular (cross-shore transport) to the beach.

Littoral zone: In beach terminology, an indefinite zone extending seaward from the shoreline to just beyond the wave breaking zone.

Longshore transport: Movement of sediment parallel to the shoreline in the surf zone by wave suspension and the longshore current.

Mean high water (MHW): A tidal datum; average height of all of the high water marks recorded at a given place over a 19-year period (Metonic Cycle).

Mean higher high water (MHHW): The mean of the higher of the two daily high waters over a long period of time.

Mean low water (MLW): Average height of all of the low water marks recorded at a given place over a 19-year period.

Mean sea level (MSL): Average height of the surface of the sea at a given place of all stages of the tide over a 19-year period. The values of mean sea level are measured with respect to the level of marks on land (called benchmarks). Water levels measured at the Unit III water control structure is set at this datum.

Neap tide: Tide occurring near the time of quadrature of the moon with the sun (first and last quarters). The neap tide range is usually 10-30% less than the mean tidal range.

Nearshore zone: Refers to the zone extending from the shoreline seaward to a short, but indefinite distance offshore, typically confined to depths less than 5 meters (16.5 feet).

National Geodetic Vertical Datum 1929 (NGVD 29): A fixed reference adopted as a standard geodetic datum for elevations; it was determined by leveling networks across the United States and sea-level measurements at 26 coastal tide stations. Water levels measured at the Unit II water control structure is set at this datum. This reference is now superseded by the North American vertical datum of 1988 (NAVD 88).

Nor'easter: On the U.S. East Coast, a low-pressure storm system whose counterclockwise winds approach the shore from the northeast as the storm passes through. These extra-tropical coastal storms often cause significant beach erosion and property damage. Wind gusts associated with these storms can approach and often exceed hurricane force effects in intensity.

North American Vertical Datum 1988 (NAVD 88): A fixed reference for elevations determined by geodetic leveling, derived from a general adjustment of the first-order terrestrial leveling networks of the United States, Canada and Mexico. NAVD 88 supersedes NGVD 29.

Overwash: Uprush and overtopping of a coastal dune or berm. Sediment is carried with the overwashing water and transported from the beach across the barrier island and is deposited in an apron-like accumulation of sand along the backside of the barrier. Overwash usually occurs during storms when waves break through the frontal dune ridge and flow landward toward the marsh.

Pleistocene: The geological epoch from 2.588 million to 12,000 years BP covering the Earth's most recent period of repeated glaciations. The end of the Pleistocene corresponds with the retreat of the last continental glacier and also with the end of the Paleolithic age used in archaeology.

Relative sea level rise: The rise of sea level measured with respect to a specified vertical datum relative to the land, which may also be changing elevation over time; typically measured using a tide gauge, which record both the movement of the land to which they are attached and the changes in global sea level.

Sediment supply: The abundance or lack of sediment in a coastal system that is available and contributes to the maintenance and evolution of barrier island and sandy beach ecosystems, and back-barrier marshes.

Shoreline: The intersection of a specified plane of water with the beach. The line representing the shoreline approximates the mean high water line.

Spring tide: The average height of the high waters during the semimonthly times of spring tides which occur at the full and new moon cycles. Spring tides rise the highest and fall the lowest from the mean sea level.

Storm surge: An abnormal rise in sea level accompanying an intense storm, whose height is the difference between the observed level of the sea surface and the level that would have occurred in the absence of the storm.

Subsidence: The downward sinking or warping of the Earth's crust relative to its surroundings; downward settling of material with little horizontal movement.

Tidal inlet: An opening in the shoreline through which tidal water penetrates the land. In our geomorphic setting, a tidal inlet formed in this way provides a connection between the Delaware Bay with some Atlantic Ocean influence and back-barrier marshes.

Tide gauge: The geographic location where tidal observations are conducted. A tide gauge consists of a water level sensor, data collection and transmission equipment, and local benchmarks that are routinely surveyed into the sensors.

Transgression: The spread or extension of the sea over land areas, and the consequent evidence of such advance; any change in sea level rise that brings offshore deep-water environments to areas formerly occupied by nearshore, often resulting in barrier island roll-over.

Washover: The sediment deposited landward of a beach by the process of overwash. Sediment transported by overwash can be deposited landward onto the upper beach or as far as back-barrier wetlands. Washover contributes to the sediment budget of barrier islands and is believed to be a major process in the retreat mechanism of some coastal barrier islands in response to sea level rise.

Wetland accretion: A process by which the surface of wetlands increases in elevation; see also accretion.

Wetland migration: A process by which tidal wetlands adjust to rising sea level by advancing inland into areas previously above the ebb and flow of the tides.